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A RECONSTRUCTION MODEL OF THE RIGHT MIDDLE AND INNER EAR.

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The model illustrated in this paper was constructed primarily with the object of facilitating the teaching of the anatomy and physiology of the ear, and also to have before us an exact reproduction of an anatomical specimen.

Method of Preparation of Microscopic Sections of the Petrous Bone.

(*a*) *Preparation of the Block of Bone containing the Middle and Inner Ear.*—As the preparation of microscopic sections of the temporal bone is a somewhat intricate and delicate process, the writers give a short account of the method employed. For a more detailed description the reader is referred to a paper by one of us (J. S. F.) in the *Journal of Laryngology, Rhinology, and Otology*, December 1913.

The temporal bone is obtained as soon as possible after death—certainly within twenty-four hours. The dura mater is divided round the internal auditory meatus, so that the nerves may not be pulled out when the dura mater is stripped from the bone to allow the fixing solution to soak in. The superior semicircular canal is opened with bone forceps to allow the fluid to enter the labyrinth. With the saw a cuboidal block, containing the more important parts of the middle and the whole of the inner ear, is now cut out from the temporal bone. The first saw cut is made in a

vertical direction at right angles to the long axis of the petrous pyramid just in front of the internal auditory meatus. The second saw cut is made parallel to and behind the first, through the mastoid antrum posterior to the semicircular canals. The third vertical saw cut is made in an antero-posterior direction through the middle cranial fossa and external auditory meatus, and runs parallel to the posterior surface of the petrous pyramid and to the middle ear cleft. The last cut is in a horizontal direction about a quarter of an inch below the internal auditory meatus, and passes through the jugular fossa.

In this way a six-sided block is obtained. The anterior wall of the external auditory meatus is now removed with bone forceps so as to expose the membrana tympani. The lining of the jugular bulb is stripped off and the anterior wall of the carotid canal is removed along with the internal carotid artery. The block is washed in running water for a minute or two to remove bone dust, and is afterwards fixed in 5 per cent. formaldehyde for one month, the fluid being changed on several occasions.

(*b*) *Decalcification, Washing, and Hardening.*—After fixation the specimen is kept in decalcifying fluid for six weeks in a wide-mouthed, glass-stoppered bottle. For decalcification Perenny's solution is recommended (HNO_3 10 per cent., 400 c.c.; abs. alc., 300 c.c.; chromic acid, 0·5 per cent., 300 c.c.). During the first week the fluid is changed daily, during the second week every second day, and during the third and subsequent weeks the fluid is changed twice weekly. After decalcification, the block is washed in running water for five days, and is then carried through gradations of alcohol till it reaches absolute alcohol. Before embedding, it is placed in alcohol and ether (equal parts) for twenty-four hours.

(*c*) *Embedding.*—The block is placed in thin celloidin for one month, and then transferred to thick celloidin for one month. At the end of the second month the celloidin is allowed to harden. The specimen is finally mounted on a stabilit block and cut with the Schantze microtome.

(*d*) *Cutting and Staining* —The specimen from which the model was made was cut in serial, vertical, transverse sections (30μ), and yielded about seven hundred sections. These were stained with Meyer's hæmalum and eosin and mounted in the usual way.

Method of Reconstruction.

For the purpose of reconstruction a drawing was made on paper of every third section at a magnification of 25 diameters by means of an Edinger projection apparatus. Each sheet of paper with its drawing was then incorporated in a wax plate 2·2 mm. in thickness. The calculation for

the above is as follows: $30 \times 25 \times 3 = 2250\mu$. The hollow spaces on the drawing were next cut out with a sharp knife on glass. The plates were superimposed in their proper order and stuck together by running a hot iron round the edges. The model was divided into several pieces, suitably painted, and finally mounted so that it could be taken apart.

Description of Model.

The model has been constructed so that the outer wall of the tympanum with malleus, incus, and chorda tympani can be removed in one piece in order to expose the inner wall. The part containing the labyrinth is divided into a series of nine segments, which can be separated from each other, so as to expose the labyrinthine structures. For convenience of recognition, the mucous membrane has been coloured pink, the ossicles white, the cut surfaces of lamellar bone light grey, the dense cartilage bone of the labyrinth capsule dark grey, nerves and endolymph spaces yellow, perilymph spaces blue, the carotid canal scarlet, the tensor tympani and stapedius muscles brown, and the jugular fossa dark blue. The cartilaginous part of the Eustachian tube at the one end, and the posterior part of the mastoid antrum at the other end, with its adjacent air-cells, are not included in the model. Owing to technical difficulties in mounting the model, it does not lie in its correct anatomical position, but is tilted backwards and inwards.

The study of this specimen has brought out several interesting anatomical facts. The convolvulus-like structure of the tympanic membrane is well shown, and is illustrated in fig. 7. The umbo of the malleus extends very low down on the tympanic membrane—beyond the most retracted point (fig. 11). The bony portion of the Eustachian tube lies immediately under the floor of the middle cranial fossa in its anterior part. The lumen is, moreover, not circular in section, but oblong (figs. 1 and 13). Its very close relation to the carotid canal is also well seen in figs. 1 and 16. The tensor tympani has a curved course: anteriorly it lies to the outer side of the tube (fig. 1), then above it (fig. 2), then on the inner wall of the tubal part of the tympanic cavity (fig. 4), and finally the tendon curves outwards across the tympanic cavity to reach the internal surface of the handle of the malleus. The high position of the opening of the tube into the cavity is worthy of note (figs. 15 and 16).

The floor of the tympanic cavity is formed by a thin convex plate of bone covering the jugular bulb. In places this plate of bone is dehiscent, there being only mucous membrane and fibrous tissue between the tympanum and jugular bulb (fig. 7). The roof of the cavity is also dehiscent

in places (fig. 10). There is a well-developed sinus tympani, which extends backwards in close relation to the ampullary end of the posterior semicircular canal (figs. 9 and 10). It passes between the posterior canal and the descending part of the facial nerve and reaches the posterior surface of the model (fig. 14). Some fairly large veins, draining the walls of the sinus tympani, pass directly into the jugular bulb (fig. 22). A great number of small air-cells in this case almost surrounded the semicircular canals, and also extended into the posterior wall of the deeper part of the external auditory meatus (fig. 10). The facial nerve, in its descending part, is completely surrounded by cells of varying size (figs. 10 and 14). Air-cells also extend forwards below and external to the Eustachian tube, and are separated by only a very thin plate of bone from the carotid artery (figs. 2, 3, and 15).

In this specimen the arrangement of the folds of mucous membrane round the ossicles was comparatively simple. The attic and the rest of the tympanic cavity communicate freely with each other. There were no folds binding the stapes to the neighbouring structures. It should be noted also that the opening of Prussak's space was situated anteriorly.

On the posterior surface of the bone the subarcuate fossa was very poorly marked (fig. 12). In it, however, was a leash of vessels, which could be traced through the bone from the mucous membrane of the inner wall of the antrum. These vessels pass through the loop formed by the superior canal (fig. 21). This route may explain the occurrence of meningitis following on acute otitis media in a case in which the labyrinth remains healthy.

It should be noted also that the eminence on the superior surface of the petrous bone does not correspond with the position of the superior semicircular canal; the latter lies distinctly anterior to the eminentia arcuata. The perilymphatic or cochlear aqueduct in this case does not open on the posterior surface of the petrous bone, but on the inferior surface, where it is in close relation to the glosso-pharyngeal nerve (fig. 2).

The bone immediately surrounding the labyrinth is quite distinct in structure from the rest of the petrous bone (figs. 17 and 19), being much denser and showing interglobular spaces, which contain cartilage cells. This dense bone is developed from the fœtal cartilage capsule, which encloses the vesicle. The modiolus of the cochlea, on the other hand, is formed of spongy membrane bone. The facial canal passes through the upper part of this capsule to reach the inner wall of the tympanic cavity (fig. 18). The bony walls of the facial canal are composed of thin lamellar bone, which is dehiscent in parts (fig. 9), and is not part of the labyrinth capsule.

The two crura of the stapes are of almost equal length, but the anterior end of the foot plate is much longer than the posterior end.

The carotid canal lies in very close relationship to the bony capsule of the cochlea (fig. 2).

The saccule is decidedly smaller than the utricle, and the neuro-epithelium of the saccule lies at right angles to that of the utricle. The ductus reuniens is still present, and can be traced from the inferior pointed extremity of the saccule along the lamina spiralis ossea of the basal cochlear coil to open into the beginning of the cochlear canal within the vestibule (figs. 23 to 29). A well-marked crista quarta is present at the point where the lower end of the utricle receives the ampullary opening of the posterior semicircular canal (fig. 30). The horizontal canal is much shorter than the two vertical canals and has a rather wider lumen. It should also be noted that the external or horizontal canal is not horizontal, as the smooth or inner end of the canal lies considerably lower than the outer or ampullary end.

The wide distribution of the air-cells in this specimen shows that it is not advisable in every case of acute mastoiditis to attempt to open up all suppurating air-cells. In the present instance such an attempt would have necessitated a labyrinth operation. In some specimens the cochlea itself may be almost surrounded by air-cells connected with the tubal part of the tympanic cavity.

In conclusion, we wish to state that this piece of work was carried out partly in the laboratory of the Royal College of Physicians, Edinburgh, and partly in the Anatomical Department of the University of Edinburgh; we wish to acknowledge our indebtedness to Professor Robinson for the use of his reconstruction apparatus. The expenses were defrayed by a grant from the Carnegie Trust.

EXPLANATION OF FIGURES.

Fig. 1. Coronal section, No. 21.

1, Tensor tympani. 2, Eustachian tube. 3, Floor of middle cranial fossa. 4, Eighth nerve in the internal meatus. 5, Posterior surface of petrous bone. 6, Glosso-pharyngeal nerve and opening of aqueduct of cochlea. 7, Marrow spaces. 8, Carotid canal.

Fig. 2. Coronal section, No. 97.

1, Tensor tympani. 2, Apical coil of cochlea. 3, Middle coil. 4, Cochlear nerve in internal meatus. 5, Cranial end of aqueduct of cochlea (perilymph). 6, Basal coil of cochlea. 7, Carotid canal. 8, Tubal portion of tympanic cavity.

Fig. 3. Coronal section, No. 127.

1, Tensor tympani. 2, Helicotrema. 3, Canal for great superficial petrosal nerve. 4, Modiolus. 5, Facial nerve. 6, Cochlear aqueduct. 7, Edge of cochlear cartilage bone capsule. 8, Carotid canal. 9. Tubal cells. 10, Tubal part of tympanic cavity.

Fig. 4. Coronal section, No. 175.

1, Tensor tympani. 2, Facial nerve passing above cochlea. 3, Vestibular ganglion. 4, Cochlear aqueduct. 5, Jugular bulb. 6. Air-cells in floor of tympanic cavity. 7, Tympanic cavity.

Fig. 5. Coronal section, No. 211.

1, Facial nerve. 2, Internal meatus with vestibular nerve. 3, Vein accompanying perilymphatic aqueduct. 4, Jugular bulb. 5, Air-cell in floor of tympanic cavity. 6, Scala tympani of basal coil. 7, Tympanic cavity. 8, Tensor tympani.

Fig. 6. Coronal section, No. 244.

1, Anterior part of epitympanic cavity. 2, Facial nerve. 3, Anterior part of utricle. 4, Cochlear opening of perilymphatic aqueduct. 5, Jugular bulb. 6, Tympanic air-cells. 7, Tympanic membrane. 8, External meatus. 9, Tympanic cavity. 10, Sacculus. 11, Tensor tympani.

Fig. 7. Coronal section, No. 295.

1, Tensor tympani. 2, Facial nerve. 3, Utricle. 4, Ampulla of superior canal with crista. 5, Opening of crus commune. 6, Superior canal. 7, Sinus of posterior canal with crista quarta. 8, Niche of round window. 9, Jugular bulb. 10, Promontory. 11, External meatus. 12, Handle of malleus attached to drum-head. 13 and 14, Head and footplate of stapes.

Fig. 8. Coronal section, No. 352.

1, External attic. 2, Head of malleus. 3, Facial nerve. 4, Two ends of external canal. 5, Superior canal. 6, Remains of fossa subarcuata in labyrinth nucleus. 7, Ductus endolymphaticus. 8, Two ends of posterior canal. 9, Jugular bulb. 10, Hypotympanum. 11, External meatus. 12, Tympanic membrane. 13, Stapes. 14, Prussak's space.

Fig. 9. Coronal section, No. 385.

1, Head of malleus. 2, Body of incus. 3, External canal. 4, Air-cells. 5, Part of endolymphatic sac. 6, Two ends of posterior canal.

Fig. 10. Coronal section, No. 523.

1, Roof of mastoid antrum. 2, Cavity of antrum. 3, Posterior canal. 4, Air-cells. 5, Saccus endolymphaticus. 6, Air-cells. 7, Sinus tympani. 8, Facial nerve. 9, Chorda tympani. 10, External meatus. 11, Border air-cells overhanging external meatus.

Fig. 11. Lateral aspect of model.

1, Short process of malleus. 2, Umbo. 3, Anterior wall of external meatus. 4, Membrana tympani. 5, Posterior wall of external meatus. 6, Air-cells.

Fig. 12. Postero-medial surface of model.

7, Subarcuate fossa. 8, Opening for saccus endolymphaticus. 9, Seventh and eighth nerves. 10, Internal meatus.

Fig. 13. Anterior surface of model.

9, Eighth nerve. 10, Internal meatus. 11, Eustachian tube. 12, Capsule of cochlea. 13, Marrow spaces. 14, Facial nerve. 15, Carotid canal. 16, Tensor tympani.

Fig. 14. Posterior surface of model.

6, Aditus. 8, Opening for saccus endolymphaticus. 12, Capsule of posterior canal. 14, Facial nerve. 17, Border air-cells. 18, Chorda tympani. 19, Sinus tympani. 20, Air-cells.

Fig. 15. Outer wall of tympanic cavity.

4, Tympanic membrane. 11, Eustachian tube. 14, Facial nerve. 15, Carotid canal. 16, Tensor tympani. 18, Chorda tympani. 20, Air-cells. 21, Handle of malleus. 22, Attic. 23, Head of malleus. 24, Body of incus. 25, Posterior ligament of incus. 26, Jugular bulb. 27, Floor of tympanum.

Fig. 16. Inner wall of tympanic cavity.

6, Air-cells of antrum. 11, Eustachian tube. 14, Facial nerve. 15, Carotid canal. 16, Tensor tympani. 19, Sinus tympani. 27, Floor of tympanum. 28, Eminence of external canal. 29, Promontory. 30, Niche of round window. 31, Stapes. 32, Facial canal.

Fig. 17. Posterior surface of segment B.

2, Helicotrema. 4, Modiolus. 9, Eighth nerve. 11, Eustachian tube. 13, Marrow spaces. 14, Facial nerve. 33, Scala tympani of basal coil. 35, Aqueduct of cochlea. 36, Scala vestibuli of basal coil.

Fig. 18. Posterior surface of segment C.

10, Fundus of internal meatus. 12, Capsule of labyrinth. 13, Marrow spaces. 14, Facial nerve. 16, Tensor tympani. 33, Scala tympani of basal coil. 34, Scala vestibuli of middle coil. 35, Aqueduct of cochlea. 39, Vein accompanying aqueduct of cochlea. 40, Vestibular ganglion.

Fig. 19. Posterior surface of segment D.

12, Labyrinth capsule. 13, Marrow spaces. 14, Facial nerve. 20, Air-cells. 26, Jugular fossa. 27, Floor of tympanum. 44, Footplate of stapes. 45, Scala vestibuli opening into vestibule. 46, Promontory. 47, Opening of aqueduct of cochlea. 48, Branch of vestibular nerve. 49, Vestibule. 50, Branch of vestibular nerve.

Fig. 20. Anterior surface of segment E.

13, Marrow spaces. 14, Facial nerve. 20, Air-cells. 26, Jugular fossa. 31, Stapes. 46, Promontory. 47, Membrane of round window. 51, Utricle. 52, Saccule. 53, Ductus reuniens.

Fig. 21. Posterior surface of E.

12, Labyrinth capsule. 13, Marrow spaces. 26, Jugular fossa. 31, Stapes. 54, Membranous superior semicircular canal. 55, Ampulla of external canal. 56, Ampulla of posterior canal. 57, Ductus endolymphaticus. 58, Posterior end of external canal. 59, Crus commune. 60, Superior canal. 61, Subarcuate veins.

Fig. 22. Posterior surface of G.

6, Air-cells. 8, Opening for saccus endolymphaticus. 14, Facial nerve. 19, Sinus tympani. 62, Posterior canal. 63, Stapedius. 65, External canal. 67, Veins from sinus tympani to jugular bulb.

Figs. 23–29. Camera lucida drawings showing the ductus reuniens. Slides 243 and 252 are drawn at a low magnification. Slides 267, 287, 294, 302, and 315 are drawn to scale at a higher magnification.

1, Utricle. 2, Saccule. 3, Aqueduct of cochlea. 4, Scala tympani. 5, Scala media. 6, Communication between scala vestibuli and perilymphatic space of vestibule. 7, Ductus reuniens. 8, Lamina spiralis ossea. 9, Membrane of round window. 10, Niche of round window.

Fig. 30. Slide 317.

1, Crista of superior canal. 2, Junction of ampulla of superior canal with utricle. 3, Perilymph space of vestibule. 4, Nucleus of labyrinth. 5, Non-ampullated end of superior membranous canal opening into utricle. 6, Lower part of utricle. 7, Crista quarta at junction of ampulla of posterior canal with utricle. 8, Neuro-epithelium (crista) of posterior canal. 9, Ductus reuniens (see fig. 29). 10, Beginning of scala tympani of cochlea. 11, Niche of round window. 12, Promontory. 13, Head and footplate of stapes. 14, Facial nerve.

A full account of the comparative anatomy of the crista quarta by Benjamin will be found in the *Zeitschrift für Ohrenheilkunde*, 1913, Band lxviii. p. 101.

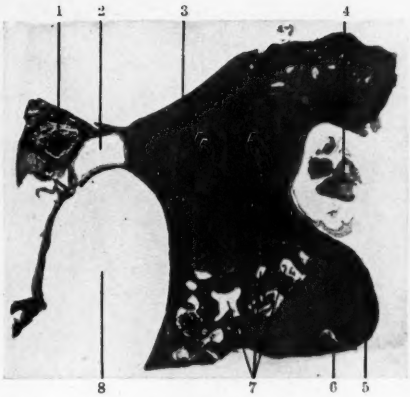


FIG. 1.—Coronal section, No. 21.

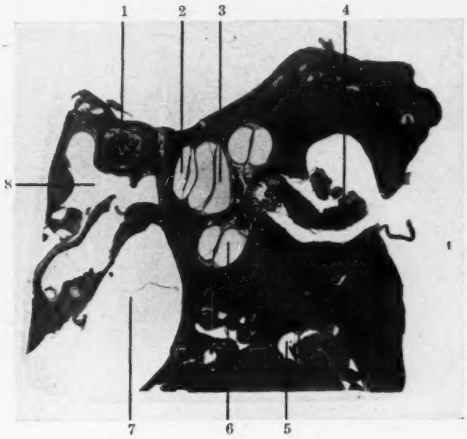


FIG. 2.—Coronal section, No. 97.

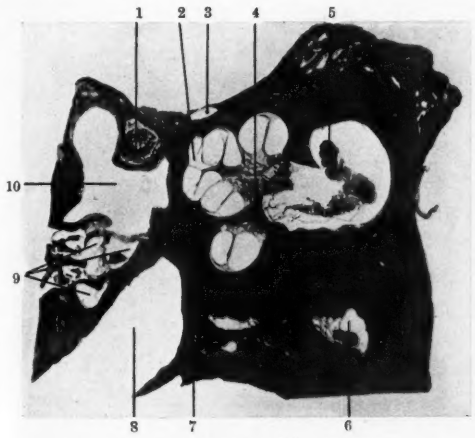


FIG. 3.—Coronal section, No. 127.

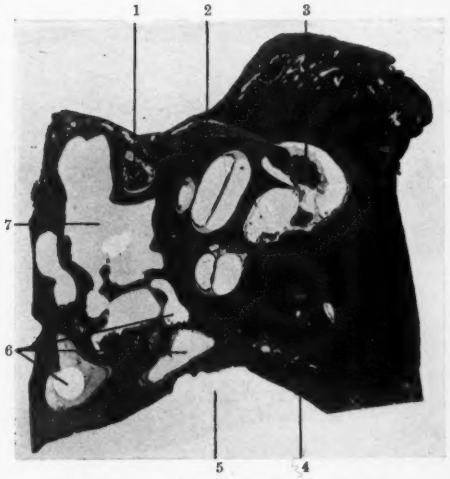


FIG. 4.—Coronal section, No. 175.

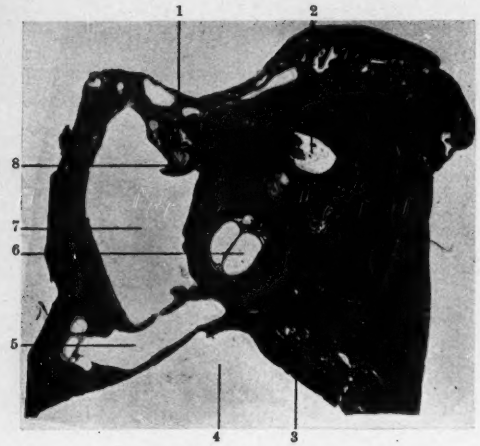


Fig. 5.—Coronal section, No. 211.

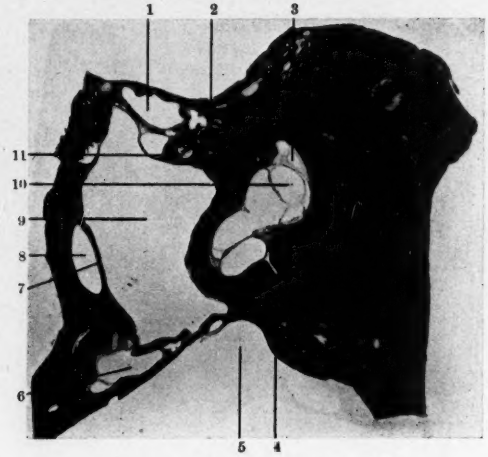


Fig. 6.—Coronal section, No. 244.

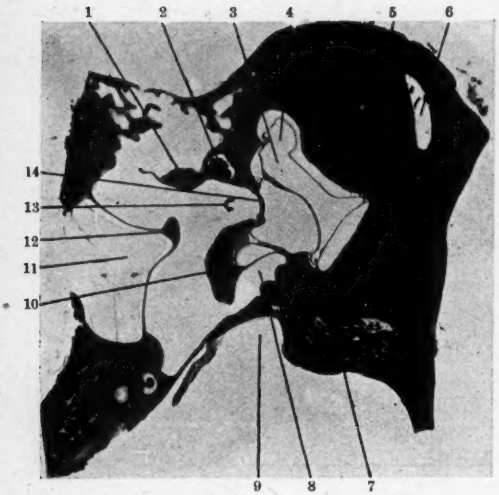
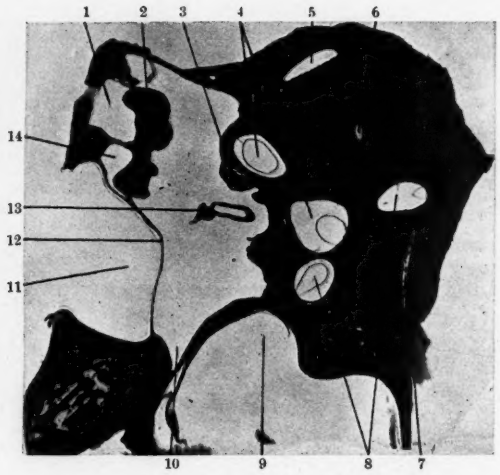


Fig. 7.—Coronal section, No. 295.



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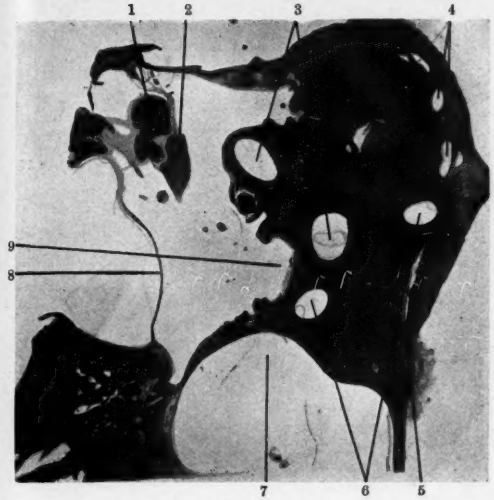

FIG. 9.—Coronal section, No. 385.

FIG. 10.—Coronal section, No. 523.

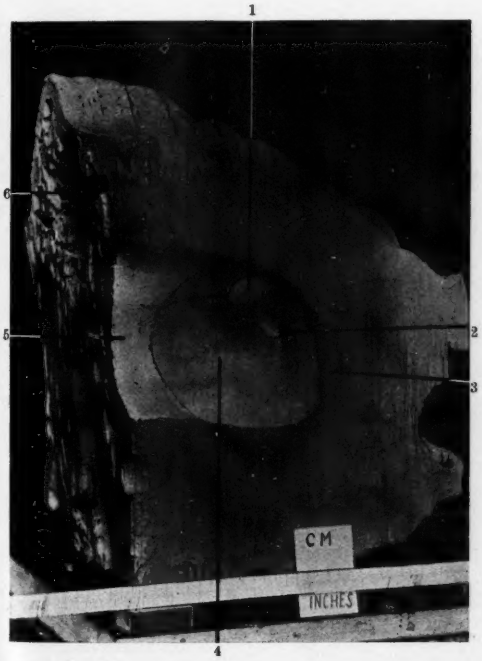

FIG. 11.—Lateral aspect of model.

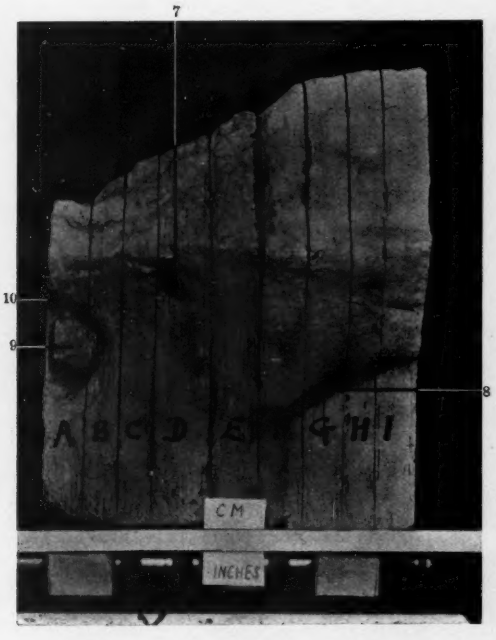

FIG. 12.—Postero-medial surface of model.

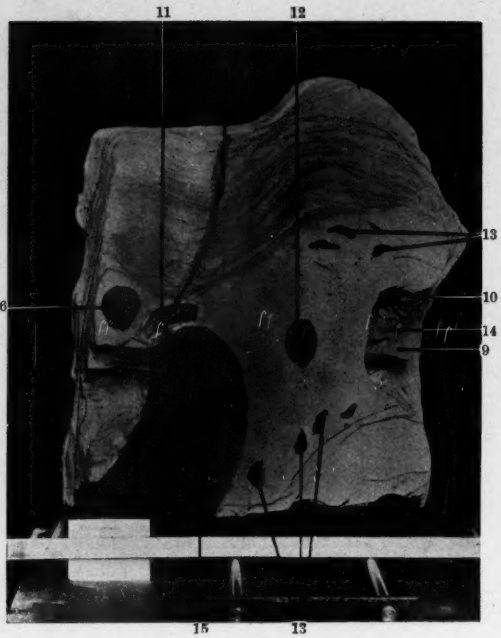

FIG. 13.—Anterior surface of model.

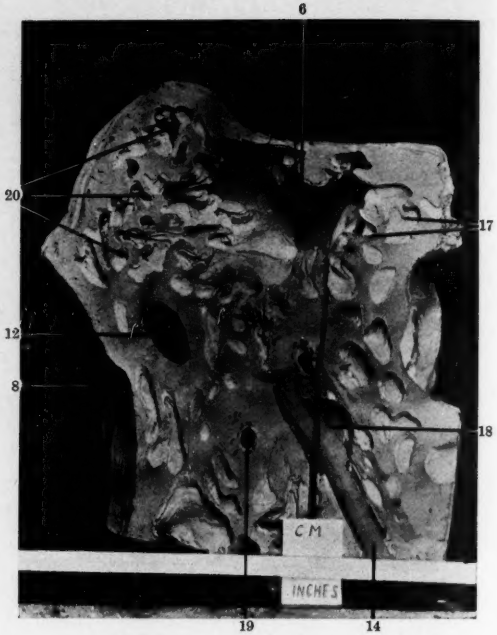

FIG. 14.—Posterior surface of model.

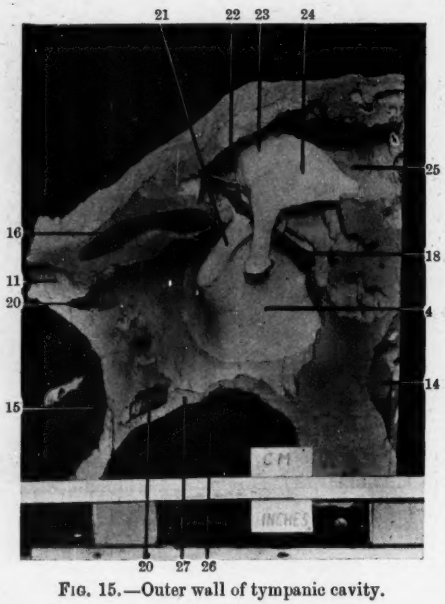

FIG. 15.—Outer wall of tympanic cavity.

FIG. 16.—Inner wall of tympanic cavity.

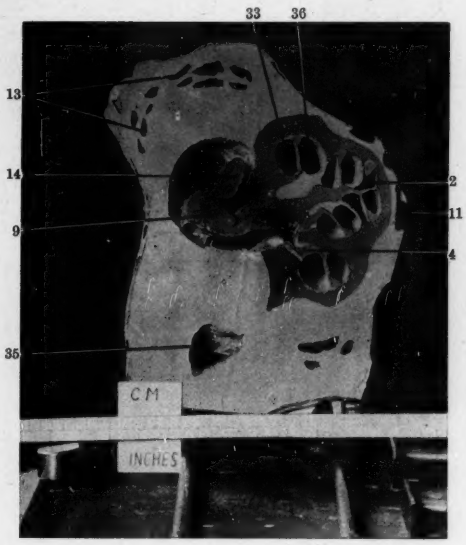

FIG. 17.—Posterior surface of segment B.

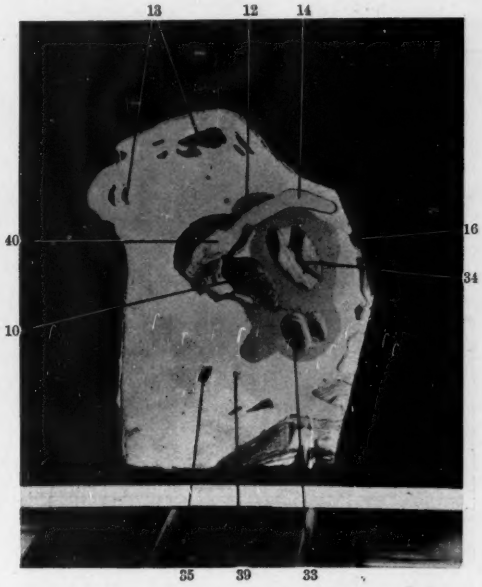

FIG. 18.—Posterior surface of segment C.

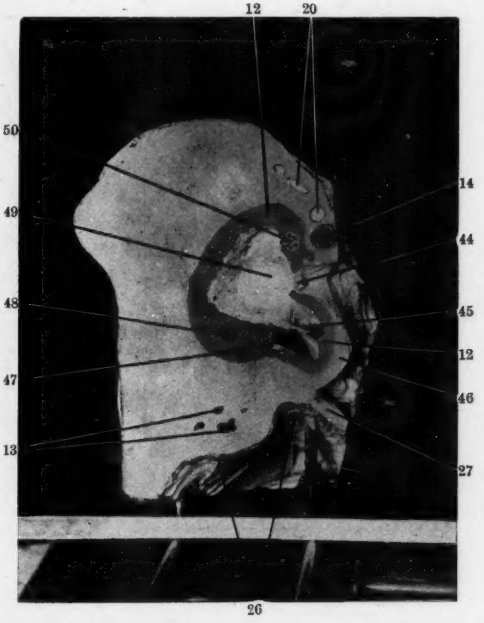

FIG. 19.—Posterior surface of segment D.

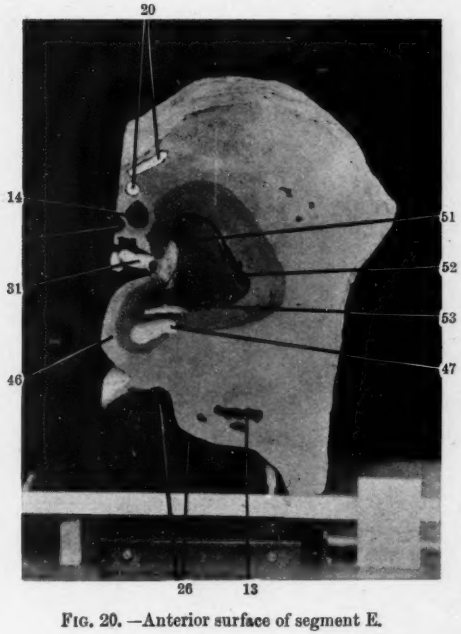

FIG. 20.—Anterior surface of segment E.

FIG. 21.—Posterior surface of E.

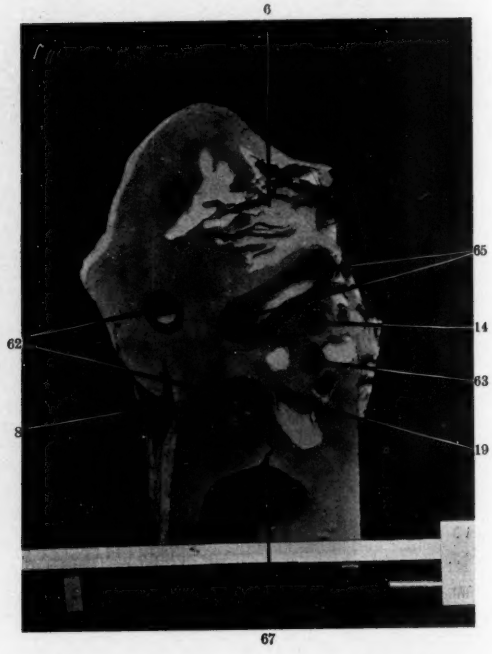

FIG. 22.—Posterior surface of G.

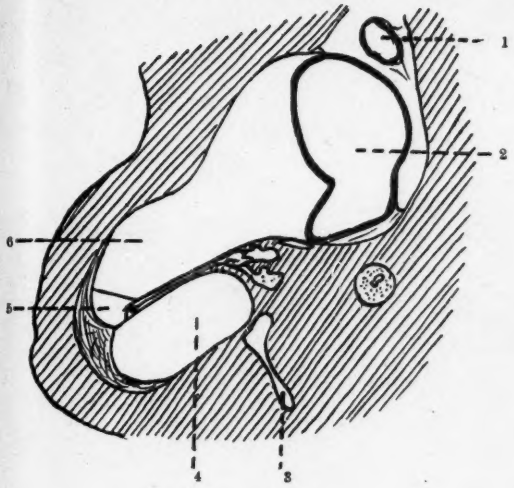

FIG. 23.—Slide 243.

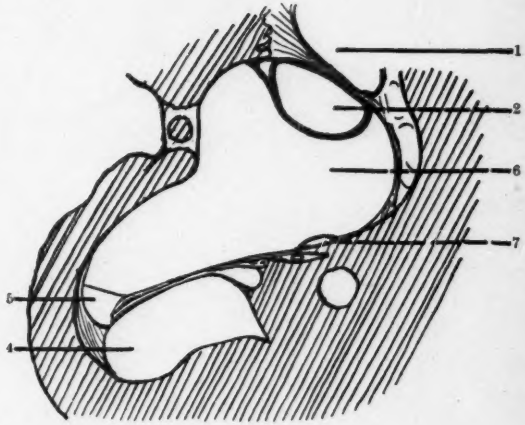

FIG. 24.—Slide 252.

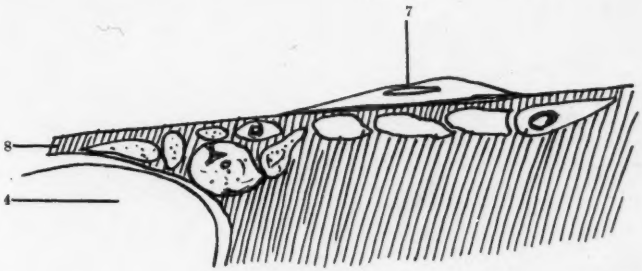

FIG. 25.—Slide 267.

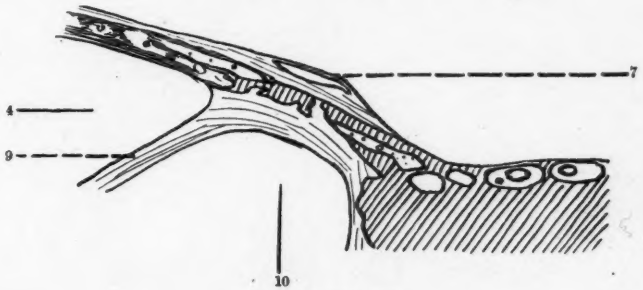

FIG. 26.—Slide 287.

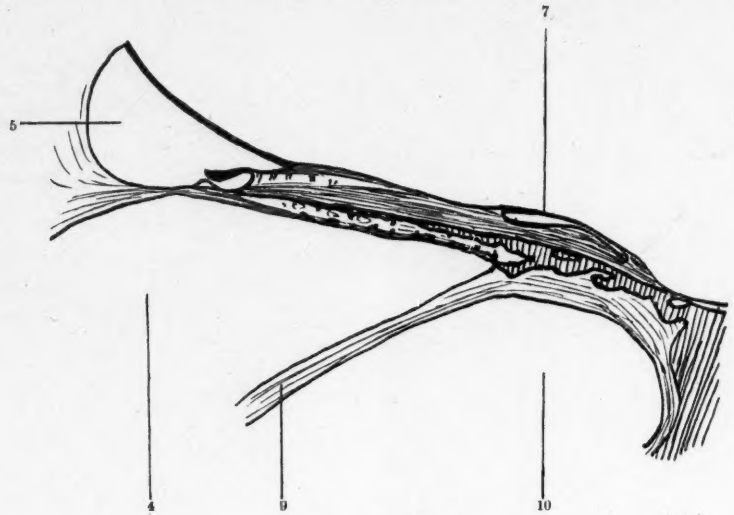

Fig. 27.—Slide 294.

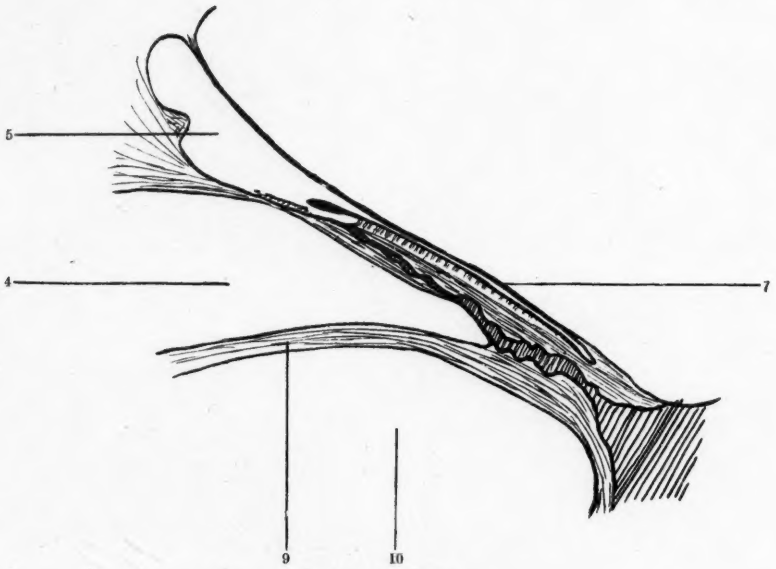

Fig. 28.—Slide 302.

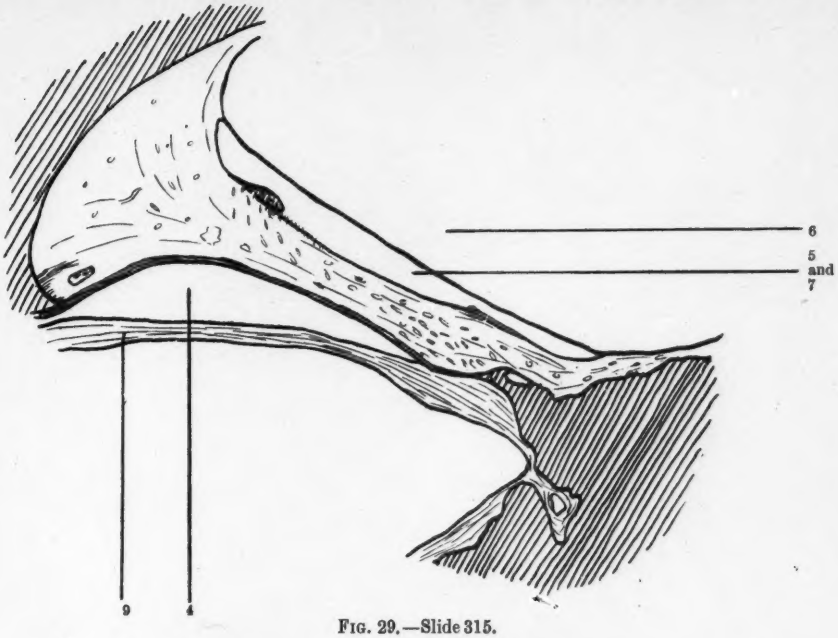

FIG. 29.—Slide 315.

FIG. 30.—Slide 317.

A CASE OF ABNORMAL DISPOSITION OF THE PERITONEUM.

By S. V. TELFER, M.B., *Demonstrator of Anatomy, University of Durham.*

THE following case from the dissecting-room of the University of Durham, College of Medicine, Newcastle-upon-Tyne, presents some points of embryological interest.

The subject was a male, æt. 54. The previous history is unknown, but the cause of death had no relation to the intestinal condition to be described.

When the abdomen was opened, the disposition of the peritoneum and the small intestine was seen to be abnormal. A large open-mouthed sac, formed by a peritoneal reflection, and containing a part of the small intestine, occupied the right side of the abdominal cavity. It extended medialwards to the right side of the vertebral column, upwards to the transverse colon, and lateralwards to the ascending colon. The anterior wall of the sac was formed by a double layer of peritoneum. The peritoneum of the posterior abdominal wall limited it behind. It was open below, and from the opening the jejunum and its mesentery issued. The anterior free margin of the opening was crescentic in shape, and was formed by that part of the root of the mesentery which normally fixes the ileum to the posterior abdominal wall (fig. 1). The sac contained about four feet of the jejunum with its mesentery. The contents were tightly packed, but there was no evidence of constriction in any part of the bowel.

The duodenum lay wholly on the right side of the vertebral column. From the pylorus it passed for a distance of one inch horizontally to the right, then vertically downwards to the level of the lower border of the second lumbar vertebra. From this point it doubled backwards on itself, and ascended almost to the level of the first part (fig. 2). The adjacent walls of the ascending and descending limbs were adherent. The bowel finally passed downwards and slightly medialwards, reaching the side of the second lumbar vertebra, where it pierced the upper wall of the abnormal peritoneal sac and became continuous with the jejunum.

The upper four feet of the latter portion of the bowel were coiled up within the sac. From the point where it emerged, the rest of the small intestine lying in the general peritoneal cavity could be easily followed to the ileo-colic junction.

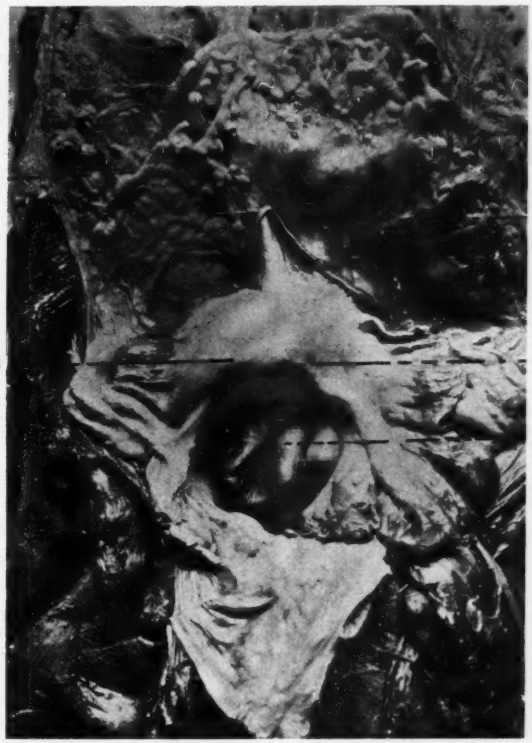
Transverse colon.
Anterior wall of sac.
Transverse meso-colon.
Crescentic margin of mouth of sac.
Coils of jejunum in mouth of sac.

FIG. 1.

The line of attachment of the mesentery was irregular. From the right side of the body of the second lumbar vertebra, in the upper limit of the sac, it could be followed down to the fourth lumbar vertebra where it emerged from the sac with the jejunum. This part of the mesentery was very short, though it contained much fat. The rest of the mesentery crossed the middle line to the left side, and passed up to the left side of the third lumbar vertebra. It finally arched to the right, forming the

anterior free margin of the mouth of the sac. It terminated at the ileo-colic junction.

The first three or four branches of the superior mesenteric artery, springing from the left convex side of the vessel, curved behind the latter, before being directed to the right, where they entered the attachment of the jejunal mesentery within the sac. The ileo-colic artery passed to the cæcum in the crescentic margin of the mouth of the sac. The situation of the right and middle colic vessels was especially noteworthy; these ran to the large intestine, between the peritoneal layers, forming the anterior wall of the sac. No branches of the superior mesenteric artery were found behind the peritoneum, which formed the posterior wall.

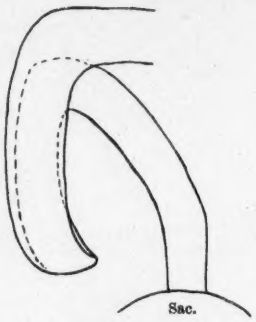

FIG. 2.—Form of duodenum (semi-diagrammatic).

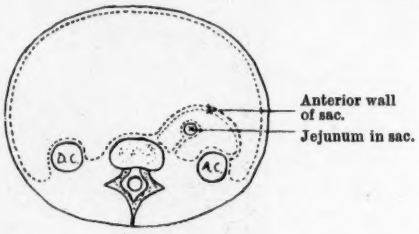

FIG. 3.—Transverse section across sac (diagrammatic).

The explanation of this condition is to be found in an abnormal process of development. About the sixth week of fœtal life, when the gut rotates on the long axis of the superior mesenteric artery, the ascending colon is carried to the right across the front of the small intestine. The mesentery accompanies the gut, and the post-arterial part which lies between the vessel and the large bowel normally disappears by fusing with the peritoneum of the posterior abdominal wall. In this case it has persisted and formed the anterior wall of the abnormal sac (fig. 3). This view is supported by the situation of the right and middle colic branches of the superior mesenteric artery, which run to the large bowel, between the folds forming the anterior wall of the sac.

It is impossible to state definitely whether the condition described above is due to the arrest of rotation of the upper portion of the gut by the adhesion of the walls of the duodenum, or whether such adhesion is secondary to failure of rotation from some other cause. The peculiar

distribution of the upper intestinal vessels, however, suggests that the adhesion of the walls is the primary factor, and this has interfered with the normal translation of the proximal portion of the gut to the left. The lower part of the small bowel has undergone the usual excursion.

While the persistence of the post-arterial part of the primitive mesentery is not uncommon, the very complete state in which it was found in this case, and the curious form and position of the duodenum, seem to be worthy of record.

A SPECIMEN SHOWING COMPLETE REMAINS OF THE LEFT SUPERIOR VENA CAVA; WITH A DESCRIPTION OF A VENULE, WHICH REPRESENTS THE "LOST" EXTRA-PERICARDIAC PORTION OF THE LEFT DUCT OF CUVIER.

By JOHN CAMERON, M.D., D.Sc., *Lecturer on Anatomy, Middlesex Hospital Medical School.*

THE writer's attention was attracted to the specimen which forms the subject of this communication by the discovery of a small yet prominent venous channel, passing from the pericardium to the left superior intercostal vein, and apparently acting as a drainage vessel for this membrane. On measurement it was found to be 42 mm. long, and 1 mm. in average breadth in the collapsed condition. It entered the left superior intercostal vein 24 mm. from the point of union of the latter with the left innominate, and exactly at the junction of what I would term its horizontal and vertical portions. The left superior intercostal vein thus makes a decided bend upwards at this point (figs. 1 and 4). It is important, therefore, to recognise at this stage that this vertical part (24 mm. long in the specimen as stated above) is the only portion of the left superior intercostal vein which will be subsequently proved to belong to the left superior vena cava, and it is, moreover, the portion derived from the left anterior cardinal vein. The horizontal part, on the other hand, corresponds to the arch of the vena azygos major (see fig. 2), and is, like it, a derivative of the posterior cardinal vein. This sudden bend of the left superior intercostal vein is thus of embryological and morphological importance.

What directed attention to the specimen first of all was the fact that the peripheral end of the venule was attached to the pericardium exactly at the origin of the left pulmonary artery, and it suddenly struck the writer that this minute and apparently insignificant vessel might represent the "lost" extra-pericardiac portion of the left duct of Cuvier, which from its very position would of course connect the fibrous cord contained in the vestigial fold of Marshall to the left superior intercostal vein, and ought therefore to be attached to the fibrous pericardium at the root of origin of the left pulmonary artery. On further examination of the specimen this early surmise was found to be correct (fig. 1).

The course of the venule was upwards and to the left over the root of the left pulmonary artery, in front of the ligamentum arteriosum (which was particularly prominent in the specimen) and upwards over the arch of the aorta, to enter the left superior intercostal vein just after the latter vessel had crossed in front of the origin of the left subclavian artery in order to gain the left innominate. Whilst crossing the arch of the aorta the venule lay 5 mm. to the right of the left vagus nerve and in front of the small cervical cardiac branches of the left vagus and sympathetic. It

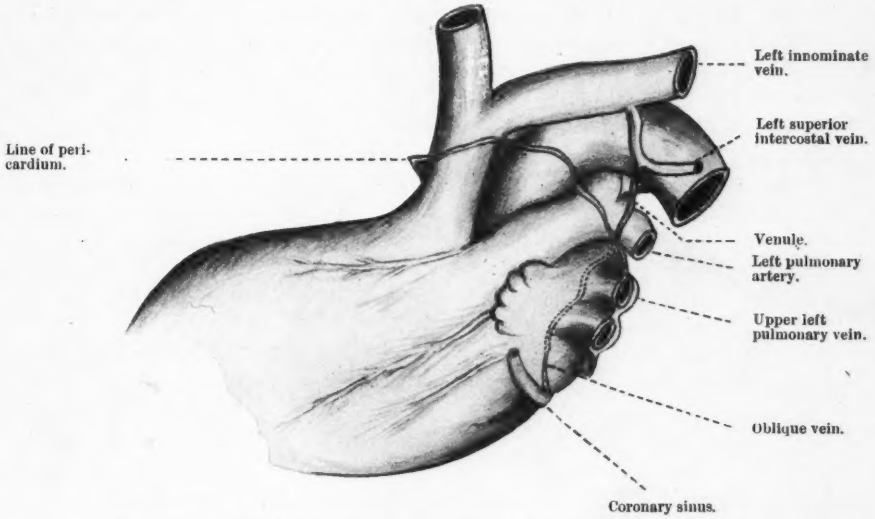

FIG. 1.—A sketch of the specimen showing complete remains of the left superior vena cava, including the venule.

was of course overlapped throughout its whole extent by the left lung and pleura. The left phrenic nerve had unfortunately been dislodged before the importance of the specimen was recognised, but I have been able to study the venule in several undisturbed thoraces, the result being to disclose a remarkably constant and characteristic relationship of this nerve to the vessel. The best method of displaying the venule in an undissected thorax is as follows:—After removal of the anterior chest wall, open the left pleural sac, pull the anterior edge of the left lung outwards, and define the position of the left phrenic nerve high up, as it lies under cover of the mediastinal pleura. Incise the mediastinal pleura along the line of the nerve, and pull the latter with its companion vessels gently to the

left. Now define the left superior intercostal vein as it crosses the aorta, and also locate the root of the left pulmonary artery just as it emerges from the fibrous pericardium. A little gentle dissection in the loose tissue occupying the interval between these points will expose the vessel in question. It can be made out without material difficulty in most cases, particularly if the veins of the thorax have been for some reason or other markedly engorged with blood immediately before death. Under these favourable conditions it will be observed that the main duty of the venule is to act as a drainage channel for the blood from the pericardium; but, in addition to this, it receives on its way upwards one or two minute tributaries from the tissues of the mediastinum. If the minute radicles of origin from the pericardium be closely examined, one of these will be found to be in direct continuity with the fibrous cord contained within the vestigial fold of Marshall; whilst the further connexion of the latter with the oblique vein is readily demonstrable.

One is now able to appreciate fully the relation of the vestigial fold to the left superior vena cava, and to compare it with the right superior vena cava. In the intrapericardial part of its course, the right superior vena cava is situated immediately in front of the right pulmonary artery and upper right pulmonary vein, and it is covered in front and at the sides by the serous pericardium. Now imagine for a moment this vessel becoming obliterated. The result would be a "vestigial fold" of serous pericardium passing from the right pulmonary artery to the upper right pulmonary vein, and containing within its anterior free border a fibrous cord representing the right superior vena cava. In other words, the vestigial fold of Marshall would be transferred to the right side, similar in every particular to the condition with which we are familiar on the left.

The writer consulted the catalogue of the Royal College of Surgeons Museum relating to the abnormalities of the venous system, and found that specimen 569.1 was a splendid example of a left superior vena cava persisting in an adult (fig. 2). In this specimen the vessel (which was actually larger than the right superior vena cava) crossed in front of the aortic arch, and passed vertically downwards *anterior to the roots of the left pulmonary artery and upper left pulmonary vein.* This relation, of course, determines the position of the vestigial fold of Marshall. It then curved backwards below the lower left pulmonary vein to become continuous with a much dilated coronary sinus. The vessel was joined at right angles on its posterior aspect by the horizontal portion of the left superior intercostal vein. The latter thus clearly corresponds to the vena azygos major (see fig. 2). It is obvious, then, that the vertical part of the left

superior intercostal vein is normally derived from the upper end of the left superior vena cava, so that one at once understands the significance of the familiar right-angled bend of the left superior intercostal. In specimen 569.1 the left innominate vein was reduced to a comparatively small cross channel which received from above a tributary presumably representing the common stem of junction of the inferior thyroid veins. The account of the specimen in the catalogue is as follows: "An adult human heart with a persistent left superior vena cava. The two venæ cavæ are united by a slender transverse vessel which receives the inferior thyroid vein."

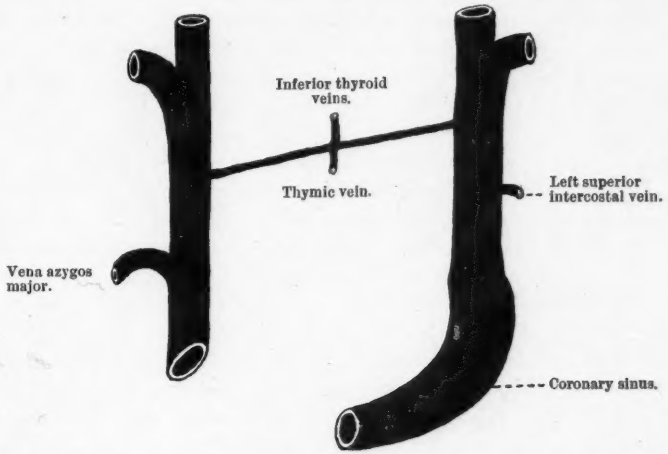

FIG. 2.—Outline sketch of the superior venæ cavæ in specimen 569.1 Royal College of Surgeons Museum. The left innominate is shown as a slender cross stem which receives the inferior thyroid and thymic veins.

A further examination of the slender left innominate vein revealed the presence of a short venous stump entering from below, directly opposite the junction of the inferior thyroid stem. This the writer regards as the thymic vein. The specimen does not show the relation of the phrenic nerves to the superior venæ cavæ.

The writer can find no description of this small pericardiac venule in text-books of anatomy. Dr R. J. Gladstone informs me that he has noticed its existence. It is usually stated that the left superior vena cava is represented in the adult by the left superior intercostal vein, the vestigial fold of Marshall, and the oblique vein. There is thus manifestly a big gap between the left superior intercostal vein and the vestigial fold, and the writer holds that the venule described above is the structure which fills

up this hiatus. If one draws a diagram of the cardinal veins and ducts of Cuvier, it will be noted that the intermediate part of the left duct becomes obliterated to form the cord in the vestigial fold. The lower segment is the oblique vein. The upper part is outside the pericardium, and must of course be connected above with the left superior intercostal vein. Professor A. Keith gives a diagram of this nature in his text-book of *Embryology*, and he, in fact, states[1] that "the extra-pericardiac part of the left duct of Cuvier joins the superior intercostal vein." The embryological evidence on the subject is thus very definite indeed.

Dr R. J. Gladstone very kindly placed at the writer's disposal a beautiful series of transverse sections of a 10-mm. human embryo, which showed the right phrenic nerve lying directly on the lateral aspect, and the vagus nerve on the mesial aspect of the right superior vena cava. The remarkable thing, however, was that the corresponding nerves of the left side bore an exactly similar relationship to the left superior vena cava (see fig. 3). The latter is of the same size as the right vessel in the 10-mm. human embryo, so that at this stage of development there is a symmetry, not only of the two venæ cavæ, but also of the phrenic and vagus nerves in relation to these. Another striking fact is that there is also a symmetrical arrangement of the tributaries of the venæ cavæ. For instance, the arch of the vena azygos major corresponds to the horizontal portion of the left superior intercostal vein (as fig. 2 shows), whilst each vena cava in addition receives pericardiac and mediastinal veins. Lying lateral to both phrenic nerves in this embryo was a small vascular channel. This the writer regards as the vein of the arteria comes nervi phrenici, a conclusion which is supported by the adult relations of these structures, as will be shown presently.

On comparing this with the adult, one finds an absolute persistence of the intimate relationship of the left phrenic nerve to the extrapericardiac remains of the left superior vena cava (represented by the venule and the left superior intercostal vein); for it will be found that it courses downwards directly lateral to the vertical portion of the latter vessel, crosses in *front* of the horizontal portion, and then runs on the lateral aspect of the venule throughout its whole course (see fig. 4). The left vagus nerve, on the other hand, always lies *behind* the horizontal portion of the left superior intercostal vein, and it may be further noted that the arch of the vena azygos major, to which this corresponds on the right side, always intervenes between the right phrenic and vagus nerves.

The vein of the left arteria comes nervi phrenici (the superior phrenic) would be found lying on the lateral aspect of the left phrenic nerve (fig. 4),

[1] Third edition, 1913, p. 285.

so that this vessel also maintains its embryonic (10-mm. embryo) relationship to the nerve (see fig. 3). This vein on being traced upwards will be found to join the horizontal portion of the left superior intercostal,

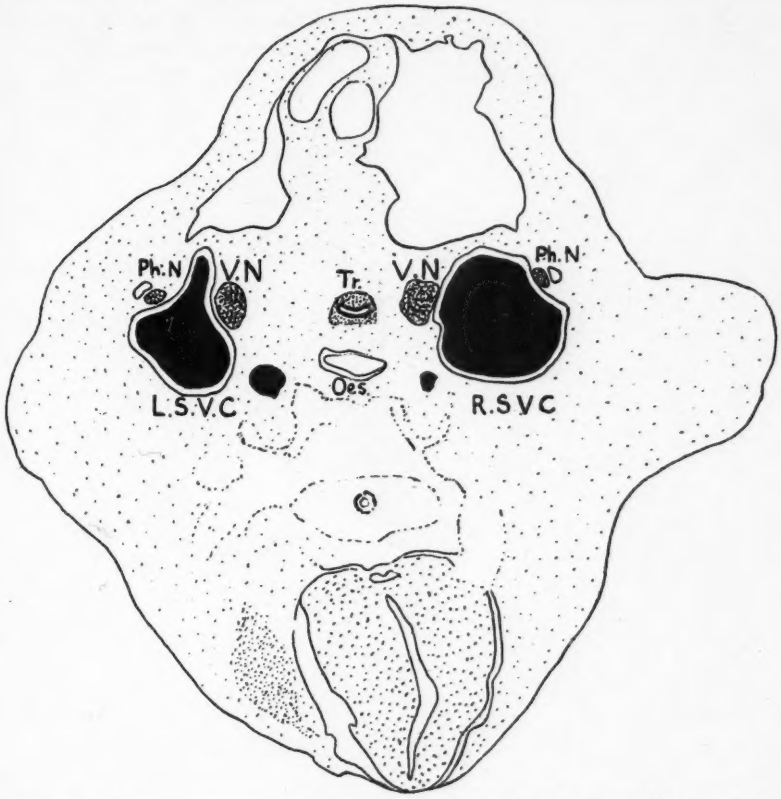

FIG. 3.—Transverse section of a 10-mm. human embryo, showing the relations of phrenic and vagus nerves to the right and left superior venæ cavæ. From a specimen kindly lent by Dr R. J. Gladstone.

usually to the left of the point where it is crossed anteriorly by the left phrenic (see fig. 4). The venule, on a casual examination, might quite readily come to be regarded as a second superior phrenic vein, but a closer inspection shows that this is not so. The writer has always concluded that the superior phrenic vein ought of necessity to join the internal mammary vein; but the above termination has been very definitely shown

in all the thoraces he has examined since his attention was directed to it. It is intended to continue this investigation in order to ascertain if this is the most common mode of termination of this vein. The only text-book of anatomy the writer has had access to, which makes a definite statement regarding the way in which this vein ends, is *Gray's Anatomy*, 18th edition, 1913, p. 684, where it is stated that the left superior intercostal vein sometimes receives the "left superior phrenic vein." It is difficult to explain

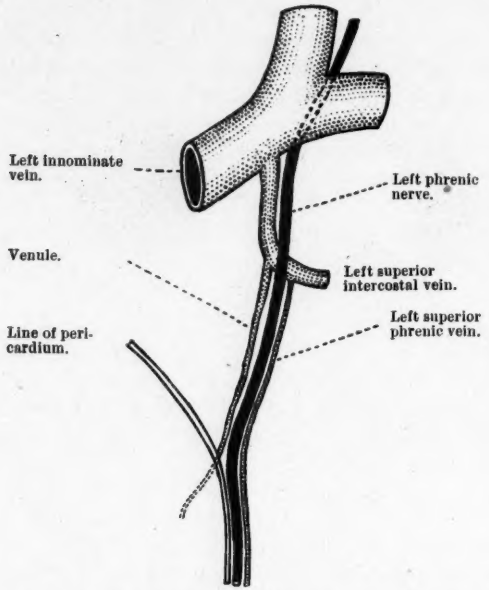

FIG. 4.—Showing the relation of the left phrenic nerve to the venule, the left superior intercostal and the left superior phrenic veins.

why veins so often exhibit this tendency to enter the first trunk they come to, instead of their own parent stem, except on the assumption that it is a result of the plexiform arrangement which is such a feature of the venous system in the embryo. In association with this idea one might note the union of the umbilical vein with the left branch of the portal, the junction of the middle sacral with the left common iliac, and above all the plexiform arrangement produced by the inferior thyroid and thymic veins which probably forms the foundation or basis of the left innominate vein. Fig. 2 is most suggestive on this question, which will be discussed more fully

in a subsequent paper dealing with the development of the left innominate vein.

In conclusion the writer wishes to express his warm thanks to Professor A. Keith for so kindly permitting the drawing of preparation 569.1 in the Royal College of Surgeons Museum, and for the keen interest he has shown in the specimen; and also to Dr R. J. Gladstone for his never-failing kindness in granting the use of his admirable series of sections of a 10-mm. human embryo.

A CASE OF DUPLICATION OF THE URETERS.

By Cecil P. G. Wakeley, *Assistant Demonstrator of Anatomy at King's College, London.*

Duplication of the ureters is of interest not only on account of its obvious surgical importance, but also on account of the bearing it has upon the study of variation from the morphological standpoint. This condition is often accompanied by other variations of the urogenital system: namely, in the position, form, and size of the kidney and in the renal arteries and veins. From a surgical point of view the mode of termination (*i.e.* a single or double opening) of the ureters in the bladder is of considerable interest; for example, in the case of stone in one ureter, if a radiographic bougie was passed into the sound ureter, an X-ray photograph would show a shadow to the side of the bougie, and it might be concluded that the shadow was not due to a renal calculus, although such existed in the second ureter.

The subject in which the present example of this anomaly occurred was a male aged 68 years in the Anatomical Laboratory, King's College. The ureters on both sides were double and pervious. Both kidneys were enlarged, the measurement of the kidneys being:—

	Right kidney.	Left kidney.	Average.
Length . .	15·2 cms.	10·4 cms.	11·5 cms.
Breadth . .	6·3 ,,	5·7 ,,	5·2 ,,
Thickness . .	5 ,,	4·5 ,,	3·2 ,,
Weight . .	170·1 grams.	143·75 grams.	127·57 grams.

The details of the condition are as follows:—On the right side each ureter commenced as a separate pelvis, the pelvis being situated at the upper and lower parts of the renal sinus respectively. The lower pelvis was the larger of the two, and divided into three large primary branches which drained the lower two-thirds of the kidney; into the calyces of these three trunks six renal papillæ opened. The upper pelvis divided into two branches into which four papillæ opened. The two pelves were completely separate, although there was no corresponding division of the renal tissue, the upper and the lower parts of the organ appearing to be continuous.

Both ureters passed downwards and medially, and the ureter from the upper pelvis crossed the ureter from the lower pelvis at the pelvic brim on the right common iliac artery. They were both crossed by the spermatic vessels, while an accessory renal artery from the abdominal aorta passed behind them to the lower pole of the kidney.

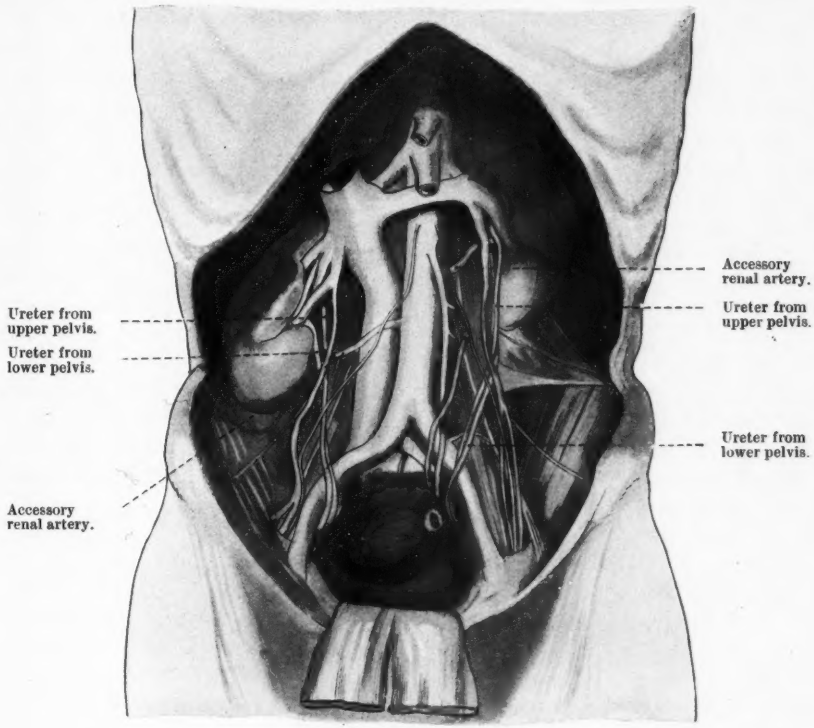

FIG. 1.—Dissection showing the relations of the kidneys, ureters, and blood-vessels.

The ureter from the upper pelvis was dilated at its lower end into an ampulla situated in the muscular wall of the bladder; this ampulla opened into the lateral angle of the trigone. The ureter from the lower pelvis opened on the mesial side of this ampulla, so that there was only one opening into the bladder on the right side. The length of the ureter from the upper pelvis was 24·5 cms., while that from the lower pelvis measured 21·5 cms.

On the left side the ureters opened by two separate orifices into the bladder; they were longer owing to the higher position of the kidney. The ureter from the upper pelvis measured 27·25 cms., that from the lower pelvis measured 24·5 cms. The division of the pelves resembled that on the right side: the upper pelvis divided into two branches, into the calyces of which three papillæ opened; the lower pelvis was the larger, as was the

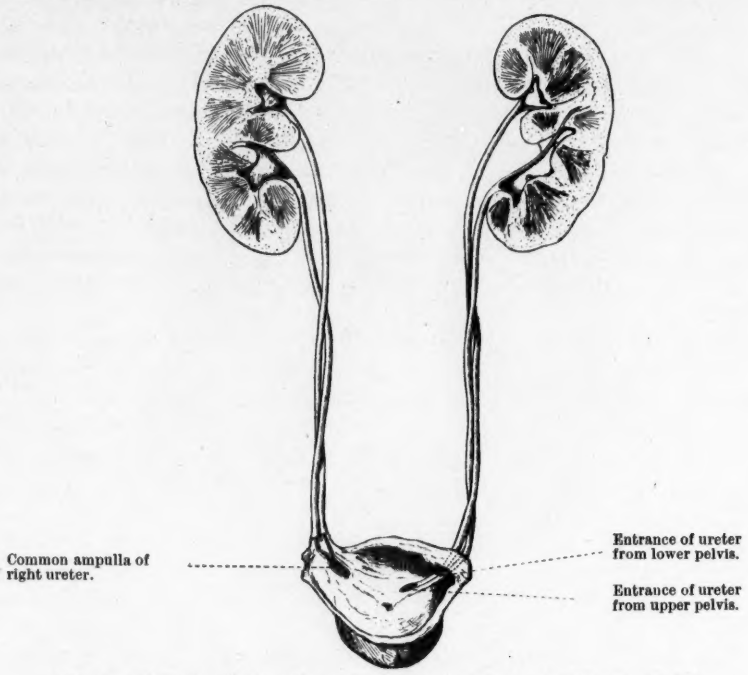

FIG. 2.—Dissection showing the mode of entrance of the ureters into the bladder.

case on the right side, and it divided into three main branches, five papillæ opening into the calyces of these branches. The ureters were crossed by the left spermatic vessels and the inferior mesenteric vein; the ureter from the higher pelvis opened on a papilla at the lateral angle of the trigone. The ureter from the lower pelvis opened higher up in the bladder posterolateral to the ureter from the upper pelvis.

Each kidney received an accessory renal artery from the aorta; on the right side it was given off 4 cms. above the bifurcation of the aorta, and passed horizontally outwards in front of the vena cava inferior and split

into several branches which entered the inferior pole of the kidney. On the left side the artery was given off 6 cms. above the bifurcation of the aorta, and passed upwards and laterally to the hilum of the kidney, and was crossed by the left spermatic vessels. The right spermatic vein joined the right renal vein.

When a double ureter is unilateral the kidney having the two ureters is frequently the larger, and its inferior extremity descends to a lower level than normal and may occasionally be joined to the opposite kidney so as to form a horseshoe kidney. The occasional occurrence of symmetrical duplication of the ureter on both sides of the body is of importance in considering the causation of the condition, for it is unlikely that any local cause would act in a similar way on both sides of the body. This fact, along with the frequency with which other abnormalities are associated with the development of kidneys having double ureters, would lead one to infer that the abnormalities are of the nature of a so-called "germinal" variation, and would thus in all probability be hereditary, and would also come into the same category of variations as dichotomy of the digits or other parts of the body.

Pohlman (7) believes that incomplete double ureter is caused by the division of the renal bud beginning too early and the division extending beyond the pelvis into the segment belonging to the ureter; where more complete splitting of the renal bud occurs so as to be affected by the absorption of that segment of the Wolffian duct which lies between the opening of the ureter and cloaca, each ureter comes to have a separate opening into the cloaca; that is, a complete double ureter is formed.

Huntington (2), on the other hand, believes that the additional ureter is derived from an additional renal bud which arises from the Wolffian duct. Of these two theories Pohlman's appears to be the more satisfactory hypothesis. In other words, it may be stated that a more complete dichotomy or division of the renal bud takes place than normally occurs. If Huntington's view be correct, one would expect to find much more frequently than is the case, additional or supernumerary kidneys which would be completely separated off from the normal kidney, and often rudimentary in size. In the case I have described there was no distinct line of separation between the two parts of the kidney. This specimen seems to favour the view put forward by Pohlman rather than that by Huntington, as one would expect to see some indication of fusion, if the two parts were originally distinct.

The frequency of additional renal arteries in these cases may possibly be explained by the larger size and lower position of the kidney than is normal; there would thus be a greater liability for one of the more distal

branches of the embryonic renal plexus being retained. This view is supported by the frequency with which the abnormal renal artery when on the right side passes in front of the vena cava inferior.

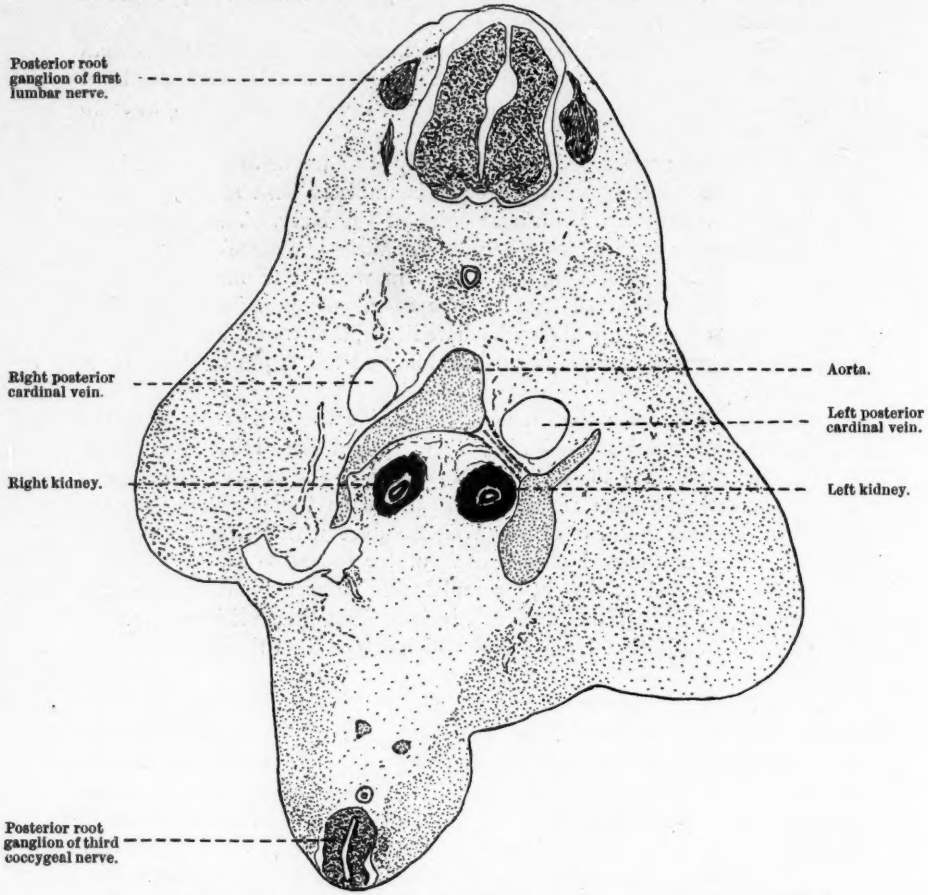

FIG. 3.—Transverse section of human embryo (10 mm. length), showing the two renal buds situated between the common iliac arteries, and ventral to the aorta and posterior cardinal veins.

The kidneys in a human embryo of 10 mm. lie ventral to and between the two common iliac arteries (see fig. 3), and also ventral and medial to the posterior cardinal veins; the arteries which the kidneys receive at

this stage also lie ventral to the posterior cardinal veins, and if they persist in the adult, would, when the right side is involved, lie in front of the vena cava inferior. In five cases of double ureter described by Abram T. Kerr (5) there were three in which additional arteries supplied the kidney having the double ureter, and in one of these the kidney received no less than four arteries, and discharged its blood by two veins into the vena cava inferior.

The arterial supply of the developing kidneys in a pig embryo of

FIG. 4.—Specimen of bilateral double ureters from a female anencephalic fœtus. The ureters on both sides opened by a common orifice into the bladder.

14 mm. has been described by Helmina Jeidell (4). At this stage the renal bud is surrounded by a capillary plexus derived from the inferior mesenteric and middle sacral arteries, and drained directly into the posterior cardinal veins or by the "vena advehentes" of the Wolffian body, and also by the inferior mesenteric vein. The plexus, which is difficult to recognise in ordinary serial sections, was demonstrated by her by means of injected embryos cut in sagittal sections 30 μ thick. These early vessels are replaced later by branches derived from the aorta, that of the right side passing behind the vena cava inferior. The earlier vessels usually disappear altogether, but may persist as permanent vessels of the kidney, as in the case I have described.

Although the renal bud when it first arises in the human embryo of three weeks, as is described by Ingalls (3), is given off from the lower end of the Wolffian duct opposite the second sacral vertebra, as soon as the embryo becomes fully curved the renal bud passes in a dorsal direction towards the level of the first lumbar vertebra which corresponds to the permanent level of the hilum of the kidney. Thus the arteries and veins formed in connexion with it at this period correspond in level to their position in the adult. When the embryo is afterwards straightened out the ureters become lengthened in a caudal direction, the kidneys themselves remaining in the position which they attain shortly after the period shown in the section of the 10-mm. human embryo.

Although rare, bilateral cases of double ureter have been recorded, and fig. 4 represents a specimen very similar to that which I have described. It was found by Dr R. J. Gladstone in an anencephalic fœtus, and is preserved in the museum of the Middlesex Hospital. The ureters on both sides emerged from a separate renal sinus and united about 1 cm. above the bladder. On each side they opened by a common orifice in the usual situation at the lateral angles of the trigone. On both sides the ureter from the upper pelvis crossed in front of the ureter from the lower pelvis and was situated below the latter at its termination. Comparing this with the specimens described by Abram T. Kerr and myself, it seems usual for the ureter arising from the upper part of the kidney to end lower in the bladder than the ureter arising from the lower part.

In conclusion, I wish to express my thanks to Professor D. Waterston and Dr R. J. Gladstone for the assistance they have given me in writing this article.

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CONGENITAL VARIATION OF THE PECTORAL MUSCLES, WITH REPORT OF A CASE.

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THE variation of the pectoral muscles in the present case is a slightly different one from any I have been able to find reported in the literature at hand. It is also of interest in that it furnishes evidence for an explanation of the origins of the variations of the pectoral muscles which, I believe, has not been offered by any of those authors who have reported "defect" of the pectoral muscles.

Absence of all or a part of the pectoralis major or of the minor, on one or both sides, is not of frequent occurrence, but, as has been pointed out by Bing[1] and others, variations occur more frequently in the pectoral muscles than in any other of the skeletal muscles. It is stated by Lengsfelder[2] that Hyrtl during his lifetime as an anatomist met with only two cases of congenital absence of the pectoral muscles. The literature relating to defect of the pectoral muscles up to 1902 has been carefully searched by Bing. He gives a rather complete bibliography up to that date. In all he was able to find reported 102 cases of absence or deficiency of the pectoral muscles. To this number, Wendel[3] adds 70 others. I have been able to find 10 cases not noted by either, and since 1904, 20 additional cases. This gives a total of 202 instances of defect of the pectoral muscles.

Regarding the frequency of defect in the skeletal musculature in general and the various combinations in which defects of the pectoral group occur, the following table taken from Bing furnishes an estimate:—

I. Pectorals		102 cases
	Pars clavicularis	6 cases
	Pars sterno-costalis	20 „
	Pectoralis major	3 „
	Pectoralis minor	3 „
	Pars clavicularis and pectoralis minor	1 „

[1] Bing, R., *Virchow's Arch.*, clxx., 1902, p. 175.
[2] Lengsfelder, M., *Wiener klin. Wochenschr.*, xv., 1902, p. 1306.
[3] Wendel, W., *Mitteil. a. d. Grenzgeb. d. Med. u. Chir.*, xiv., 1905, p. 456.

	Pectoralis major and pectoralis minor	26 cases
	Pars sterno-costalis and pectoralis minor	36 „
	Pectoralis major and pectoralis minor (right), with Pars sterno-costalis and pectoralis minor (left)	1 „
	Undetermined	6 „
II.	Cucullaris	18 cases
III.	Serratus anticus major	14 „
IV.	Quadratus femoris	16 „
V.	Omohyoïdeus	8 „
VI.	Semimembranosus	7 „
VII.	Abdominal muscles	4 „
VIII.	Gemelli	4 „
IX.	Deltoïdeus	4 „
X.	Latissimus	4 „
XI.	Sterno-cleidomastoid	3 „
XII.	Rhomboïdei	3 „
XIII.	Supra- and infra-spinatus	3 „
XIV.	Biceps brachii	3 „
XV.	Small hand muscles	2 „
XVI.	Quadriceps femoris	2 „
XVII.	Platysma	2 „
XVIII.	Extensor carpi ulnaris	2 „
XIX.	Longissimus dorsi	1 „
XX.	Supinator longus	1 „
XXI.	Levator scapuli	1 „
XXII.	Intercostals	1 „
XXIII.	Face muscles	1 „
XXIV.	Gastrocnemius	1 „
XXV.	Subclavius	1 „
XXVI.	Triceps brachii	1 „
XXVII.	Brachialis int.	1 „
XXVIII.	Glutæi	1 „
XXIX.	Extensor digiti V.-proprius	1 „
XXX.	Extensor digitorum sublimis	1 „
XXXI.	Stylohyoïdeus	1 „

Of the 214 cases of absence of skeletal muscle in this table, 102, or nearly one-half, were cases of absence of the pectorals. This is a relatively high proportion. However, as Bing points out, this proportion is too high, and for at least two reasons: (1) absence of a pectoral muscle is so easily detected in the clinic; and (2) on account of a somatic and thoracic deformity a physician is nearly always consulted. Such is not the case with the smaller and less apparent muscles. Yet, making allowance for this, there probably remains a large percentage for the pectorals. "Regarding the absolute frequency of 'Brustmuskeldefecte,' the following data of Schlesinger's will give an idea: he saw in Schrötter's clinic in

Vienna among a sick list of 54,000 patients 5 cases, an average of about 1 in 11,000" (Bing).

An analysis of the cases of congenital absence of pectoral muscles will substantiate the statements of Lengsfelder: "It is further the most frequent combination, that the sterno-costal portion of the m. pectoralis major and the pectoralis minor are absent," and also, "Bilateral defect, isolated absence of the clavicular portion, isolated absence of m. pectoralis minor, are rarities." Further, as noted by Wendel ('05), "In the literature there is found only a single case (observed clinically) of bilateral congenital Brustmuskeldefekt." Of all the cases of congenital absence of pectoral musculature reported up to 1911 there is only one instance in which heredity as a causal factor might be considered. This is, I believe, the only instance in which absence of a pectoral muscle has occurred in more than one member of a given family. Greif reports congenital absence of the pectoralis major and minor (left) in his father and brother, and a poorly developed pectoral musculature in himself. As regards other muscles, Fürstner [1] reports congenital quadriceps muscle defect in two brothers.

In many of the cases reported pectoral muscle defect has been accompanied by either extensive congenital malformations and deformities of neighbouring parts, or pronounced pathologic lesions in the skeleton and skeletal musculature. The number of instances of simple congenital defect or absence of the pectoral muscles is thus reduced. An analysis of the literature seems to show that congenital deformity of the pectoral group does occur most frequently in conjunction with more or less extensive malformations of neighbouring structures. For instance, scarcity of hair, fascia, and fat in the pectoral region and axilla, displacement and atrophic condition of the mammary gland, tightness of skin, defective development of the ribs and intercostal muscles, and of the neighbouring shoulder muscles on the affected side, singly or in various combinations, are reported as most frequently associated with congenital defect of the pectoral muscles.

In so far as I am able to determine, the clavicular portion of the pectoralis major was present in nearly every congenital case, and was even somewhat hypertrophied. In some cases the deltoid also appeared hypertrophied. Those of the living subjects who were in good physical condition showed no inconvenience or awkwardness on account of the muscular deficiency. Thus Burke's patient (absence of sterno-costal portion of pectoralis major and all of the pectoralis minor on the left side) was a good baseball pitcher (left-handed), the patient of Bruns [2] was one of the

[1] Fürstner, *Archiv f. Psych.*, xxvii. 2, 1895, p. 607.
[2] Eulenberg, A., *Deut. med. Wochenschr.*, xxxv., 1877, p. 413.

best "turner," that of Eichhorst [1] "sächträger," the student of Fränkel [1] "ein ausgezeichneter Fechter," and Stintzing's [2] patient (defect left) fenced left-handed.

Huntington [3] has traced the phylogeny of the pectoral muscles through the primates, and finds that these muscles present a great many variations in the different groups. Both pectoralis major and pectoralis minor show a great tendency to vary. The most common variations, however, are those of the pectoralis abdominalis, both in its relation to the pectorales major and minor and to the axillary arch. As the pectoral muscles are among the last to be acquired, it is not surprising that they show so many variations in man. On the other hand, that portion which is acquired last (*i.e.* the clavicular portion of the pectoralis major) shows the fewest variations. Huntington has also shown that in the primate series the pectoral muscle mass is early differentiated into superficial and deep layers of "sharply defined individuality," corresponding to the pectoralis major and minor in man respectively. Thus isolated absence of the pectoralis minor is not readily to be explained as a reversion. That congenital pectoral muscle defects in general do not represent reversions is made probable by the striking absence of bilateral defects. As Wendel (1905) points out, congenital pectoral muscle defects are (with a single exception) always unilateral.

The present variation (left side) was observed in a muscular, well-developed male Filipino subject in the dissecting-room. The skeletal musculature was well developed throughout, and no other variations of the muscles were observed.

Right.—The pectoralis major on the right side is well developed and of normal appearance. There is no distinct line of separation between pars clavicularis and pars sterno-costalis, and the pars abdominalis (not illustrated) is small. The muscle arises from the medial two-fifths of the clavicle, the capsule of the sterno-clavicular articulation, from the anterior surface of the sternum for its entire length, and from the anterior surfaces of the medial ends of the 1st to 7th costal cartilages. The small pars abdominalis arises from the anterior leaf of the vagina m. recti abdominis. Insertion: crista tuberculi majoris humeri.

The pectoralis minor arises by fleshy and fibrous digitations from the 2nd to 5th ribs inclusive and the fibrous sheaths of the adjoining intercostal muscles. It is inserted into the processus coracoideus scapulæ, some fibres going over into the capsule of the shoulder articulation.

Innervation of both muscles: nn. thoracales anteriores.

[1] Cited by Lengsfelder (2).
[2] Cited by Bing (1).
[3] Huntington, Geo. S., *Amer. Jour. Anat.*, ii., 1903, p. 157.

Left.—The pectoralis major on the left side consists of two parts: a large, apparently hypertrophied pars clavicularis and a small pars sterno-costalis. These two portions are well separated from each other. The pars clavicularis arises from the medial half of clavicle, with a few fibres

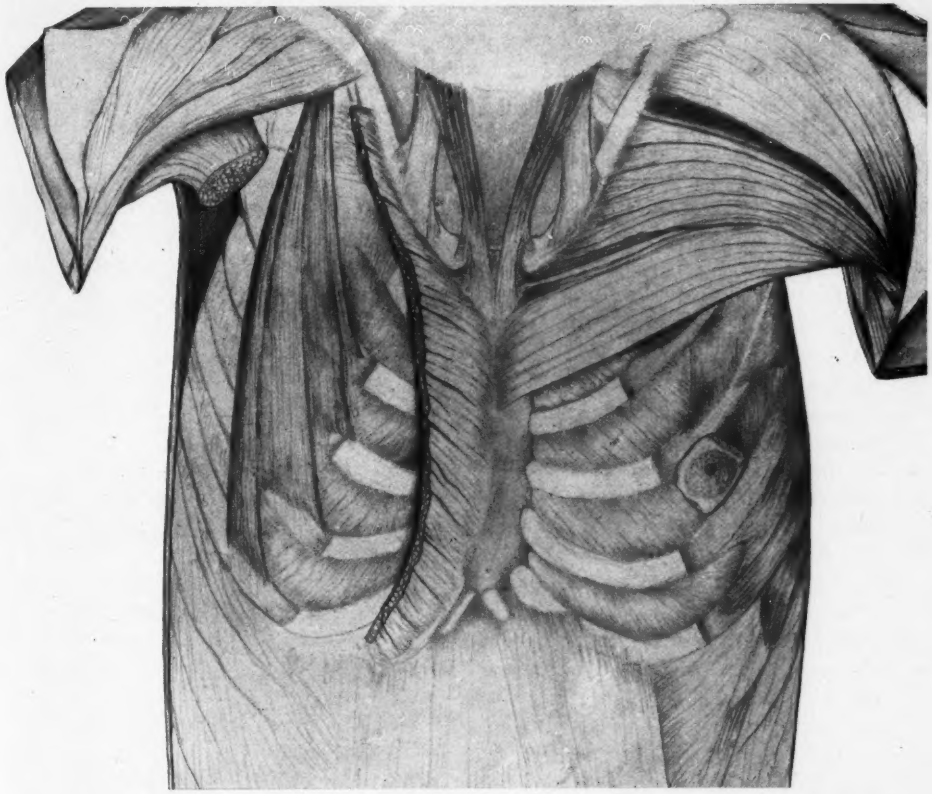

FIG. 1.—On the right side there is a well-developed pectoralis minor. The pectoralis major is a broad flat muscle not separable into clavicular and sterno-costal portions. The pars abdominalis has been removed. On the left the pectoralis minor is entirely wanting. The pars clavicularis of the pectoralis major appears hypertrophied. The small pars sterno-costalis is likewise thick, and the fibres run in coarse bundles. Its fleshy origin does not extend below the 2nd costal cartilage. The left mamma is over the 4th intercostal space.

also from the capsule of the sterno-clavicular articulation. The pars sterno-costalis arises from the anterior surface of the upper part of the sternum between the incisura clavicularis and the 3rd sterno-costal

articulation, and from the anterior surface of the medial 2·5 cm. of the 2nd costal cartilage. The two portions are inserted by a common tendon into the crista tuberculi majoris humeri. The pars sterno-costalis is 5·5 cm. in its greatest breadth and 2 cm. in its greatest thickness. The muscle fibres in both pars clavicularis and pars sterno-costalis run in coarse bundles. The pars sterno-costalis courses lateralward, the lower half of the fibres taking a somewhat spiral course, to form the posterior portion of the tendon of insertion. The fibres of the pars clavicularis pursue an almost parallel course, slightly converging laterally and running anterior to those of the pars sterno-costalis to form the anterior portion of the tendon of insertion. The whole muscle is enclosed in a very tough, thick fascial sheath. This sheath is more abundant over the pars sterno-costalis. Innervation: nn. thoracales anteriores.

Pectoralis minor.—No trace of a pectoralis minor can be found. The fascial sheath above referred to is especially strong and heavy in the location of the absent pectoralis minor. It is continuous superiorly with the costo-coracoid membrane, being attached to the upper two ribs, and inferiorly extends into the sheath of the serratus anterior and under the mamma. Laterally it becomes very thin and goes over into the axillary fascia. No muscle fibres nor any indication of a degenerated muscle can be found in this fascia.

On the left side there is no perceptible deficiency of fat, fascia, or hair; the skin is not closely adherent to the thorax, and there is no defective development of the ribs or intercostal muscles. The papillæ are approximately symmetrical in position.

The variation in the present subject differs from the great majority of those found in the literature in that there is a total absence of the pectoralis minor and only a partial absence of the pars sterno-costalis of the pectoralis major. From the normal appearance of all the neighbouring structures and the entire absence of any trace of muscle fibres of the pectoralis minor, the conclusion is justified that the condition is congenital.

Before attempting an explanation of congenital pectoral muscle defect, a few remarks concerning the development of the pectoral muscles are necessary. W. H. Lewis[1] has shown that:—

"The pectoral premuscle mass from which both the mm. pectoralis major and minor arise is clearly indicated in a 9-mm. embryo. It lies in the lower cervical region on the medial side of the arm bud. This premuscle mass is widely continuous with the arm premuscle sheath, and lies almost entirely anterior to the 1st rib. In an 11-mm. embryo it reaches about

[1] Lewis, W. H., in Mall and Keibel's *Manual of Human Embryology*, Philadelphia, 1910, vol. i. p. 487.

the level of the 3rd rib, but the two muscles still form a single columnar mass attached to the humerus, to the coracoid process, and to the *clavicular* rudiment. As the mass differentiates, it flattens out and extends caudo-ventrally to the region of the distal ends of the upper ribs. In a 14-mm. embryo the caudal end of the muscle has extended near to the tip of the 5th rib and the muscle has begun to assume more the adult form, with fibres arising from the upper five ribs and sternal anlage as well as from the clavicle. At this stage the proximal portion of the muscle has split into the major and minor portions, the one attached by tendon to the humerus and the other to the coracoid process. Both muscles fuse together near the costal attachments. In a 16-mm. embryo the two muscles are quite distinct, the pectoralis major now extending to the 6th rib and showing a distinct cleavage between the costal and clavicular portions. The pectoralis minor has now its distinct attachment to the 2nd, 3rd, and 4th ribs."

Regarding an embryological explanation of the congenital absence of the pectoralis minor and the pars sterno-costalis of the pectoralis major there are three possibilities:—

1. These structures may fail to develop in the embryo.
2. There may be a formation of the anlage and a partial development of the muscles, but, failing to become attached to the bones, part of the muscles subsequently atrophies.
3. That portion of the premuscle mass which in normal development goes to form the pectoralis minor and two portions of the pectoralis major may more or less completely fail of subsequent differentiation into its separate parts.

According to Lewis,[1] "the pectoralis major muscle (*i.e.* pars clavicularis and pars sterno-costalis) arises, in common with the minor, from a premuscle tissue which is located for the most part above the 1st rib." It early forms an attachment to the clavicle. "It gradually migrates or shifts to the costal region, as has already been noted by Dr Mall."

With the exception of those cases involving extensive malformations of the neighbouring structures, the instances in which there is an entire absence of all the pectoral musculature on either one or both sides are extremely rare. These facts make it probable that the first consideration (*i.e.* that there is lack of development of the pectoral musculature in the embryo) is responsible at most for only a very small percentage of pectoral muscle defects.

Regarding the other two possibilities—(2) failure of attachment and subsequent atrophy of the pectoralis minor and pars sterno-costalis of

[1] Lewis, W. H., *Johns Hopkins Hospital Bulletin*, xii., 1901, p. 172.

pectoralis major, and (3) lack of complete differentiation—it is probable that both are separately concerned in producing congenital pectoral muscle defect. However, the evidence available is not sufficient to indicate a preference. That there may occur in some cases an incomplete differentiation is indicated by the fact that absence of the pectoralis minor and pars sterno-costalis of the pectoralis major is usually associated with a hypertrophied pars clavicularis, which latter, so far as histologic examination has been made, contains an increased number of muscle cells—more than in any other skeletal muscle. In this case we might also expect a deficiency of fascia in the pectoral region of the affected side, since, the thoracic portions of the pectorals failing to migrate ventro-caudally, the fascial tissue would likewise not be brought down. The migration ventro-caudally of this pectoral muscle mass would probably also have an influence on the overlying portions of the skin, and in the event of no migration the mammary gland would be located at a higher level and more laterally. These two conditions have been most frequently described as accompanying congenital absence of the pectoralis minor and the pars sterno-costalis of the pectoralis major.

The second possibility is essentially that advocated by Lewis: "It would seem that in the conditions existing between an embryo of 9 and 11 mm. in length might be found a partial explanation of such varieties as absence of the sterno-costal or clavicular portions and of the pectoralis minor with the sterno-costal portion. We have here a condition in which the clavicle is absent and no attachment to the ribs exists. The subsequent attachment to one or the other might not occur and that portion of the muscle be found wanting in the adult. With absence of the sterno-costal portion would be associated that of the pectoralis minor owing to their early fusion."[1]

When the differentiation takes place and there is a failure of attachment to the thorax and a subsequent atrophy of the muscle mass, we would expect at least the normal amount of fascia and fat, a normal position of the mamma, and that the deformity might not be apparent in early childhood. These conditions have also been frequently met with. This hypothesis would also offer an explanation for the loose fold of skin forming the anterior axillary wall and extending ventro-caudally to the mamma, and termed by several authors "Flughaut." Of the cases reported up to 1907 Loening says: "In the location of the absent breast muscles

[1] A suggestion of Bing which may account for the arrest of migration and a consequent failure of attachment of the pars sterno-costalis and the pectoralis minor is perhaps worthy of notice. In his opinion the chin pressing against the anterior thoracic wall during intra-uterine life would account for absence of these muscles on that side. It is easy to suppose that such an impediment might prevent the caudo-ventral migration of these parts.

there often occurred stretched out between the thorax and the upper arm a skin fold (Flughaut) which consisted of a fairly compact fibrous tissue, for the most part enclosing within itself no rests of muscle substance."

A discussion of the underlying factors which are responsible for a failure of formation of the pectoral muscle mass, a failure of its differentiation, or the failure of the differentiated muscles to make attachment, are beyond the scope of this paper.

In the present case, in which there is an absence of the pectoralis minor and the greater portion of the pars sterno-costalis of the pectoralis major, there is, I believe, only one plausible explanation: namely, that the condition is congenital, and that the pectoralis minor, failing to find its costal attachment, underwent degeneration, and that the pars sterno-costalis of the pectoralis major did not make attachment below the 3rd costal cartilage.

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[1] This list of references includes only those which are not given by Bing (1) and Wendel (3). Some of them have been collected from other articles, from the *Index Medicus*, and from the Index Catalogue of the Library of the Surgeon-General's Office, United States Army.

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THE HUMAN STOMACH AND THE CANALIS GASTRICUS (LEWIS).

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INTRODUCTION.

So much has been written about the normal human stomach and its shape, that one hesitates to embark upon a subject to all appearances so well worn.

It has been a commonplace of comparative anatomy for many years that ruminant animals possess the power of swallowing fluid directly into the pyloric portions of their stomachs without its mingling with the more solid food in the cardiac sacs. Later, it was shown that carnivorous animals—notwithstanding their simple, single-chambered stomachs—possess the same faculty. Since that time, the minds of anatomists have been much exercised in a desire to prove or disprove that the same is true of human beings. Waldeyer (1), who wrote an exhaustive paper in support of this theory and called the potential passage the "Magenstrasse," suggests that a solution to the question should be readily found by means of X-rays. This idea had already suggested itself to me, and the investigation was begun some eighteen months ago. So far as I am aware, no one has attempted this work, the results of which are here set down.

COMPARATIVE ANATOMY.

A brief sketch of the comparative side of the subject may be of help to the reader. Ruminant animals swallow their food, as they graze, into the first and second stomachs (rumen and reticulum). Here it is stored until a time favourable for mastication presents itself. A suitable quantity is then returned to the mouth by a sharp contraction of the abdominal muscles. This is the method of return of the food in ruminating human

beings (Brockbank (2), and Lemoine and Linossier (3)), as antiperistalsis is unknown in the œsophagus. After the bolus has been well masticated by the familiar side-to-side movement of the jaws, it is again swallowed. It does not, however, return to the saccular first or second stomachs, but this time it passes on to the third stomach (psalterium), whence it is rapidly expelled into the fourth (abomasus) and so into the duodenum. The passage of the soft, chewed bolus into the pyloric portion of the ruminant's stomach is accomplished by means of the sulcus salivalis (Retzius) or

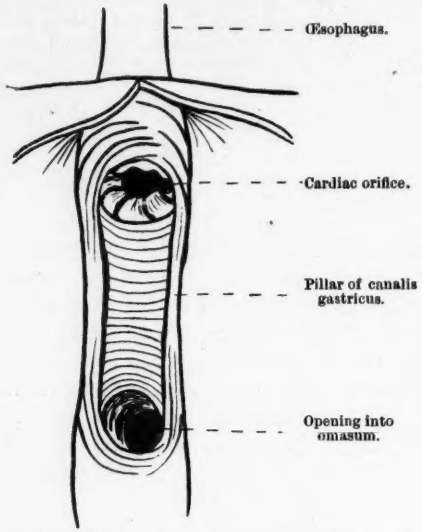

Fig. 1. —The sulcus œsophagus (canalis gastricus) of the ruminant. Mucosa stripped off to show muscular fibres. (After Carpenter.)

canalis gastricus of Lewis (fig. 1). This canal varies in completeness. In some animals it is a veritable tunnel, the lips of which have to be forcibly separated in order to view its interior. The longitudinal muscle fibres contained in its borders, by their contraction, approximate the lips of the canal and also shorten it. Thus Home (4) described the ox's stomach: "When the food is swallowed the second time, the orifice of the third cavity is brought forwards by the muscular bands which terminate in it, so as to oppose the end of the œsophagus and receive the morsel without the smallest risk of its dropping into the second."

In suckling ruminants the milk flows directly into the psalterium and abomasus (Owen (5)). In animals with simpler stomachs the following

observations have been made: Cohnheim (6) found that, in the dog, water did not mix with the general food in the stomach, but passed on as it was to the pylorus—an occurrence at which he was greatly surprised. The dog's stomach is to all appearances quite innocent of any groove or canal along the lesser curvature. I have found this to be equally true of the horse's stomach, yet Colin (7) by the most exhaustive experiments on the live horse came to the same conclusion, namely, that water passed straight on into the pyloric portion, its descent being made along the lesser curvature. Smith (8) is of the same opinion. Since neither of these simpler-stomached animals has any salient canal, this selective action must be a purely physiological one, and probably due to specialised contraction of a portion of the gastric musculature.

Analysis of Existing Evidence of the Presence of the Canalis Gastricus in Man.

Under the name of canalis gastricus, Lewis has called attention, in a recent and wholly admirable paper (9), to a canal along the lesser curvature of the human fœtal stomach. It is surprising that it has received so little attention in England, as it has from time to time called forth considerable discussion on the Continent. Lewis gives some excellent reconstruction models in his paper, and describes the channel as follows:—It "follows the lesser curvature, appearing as a groove when seen from the inside of the stomach. It suggests a continuation of the œsophagus, split open towards the gastric cavity . . . an open canal which . . . may become a tube during its physiological activity, by the approximation of its lips" (*loc. cit.*, p. 486).

His own view is that in the human embryo it is a definite, epithelial structure, since it appears before the oblique muscle fibres, at whose door the responsibility of forming the canal had been laid by Kaufmann (10). Viewed from the inside in Lewis's model of the stomach of a 44·3-mm. embryo (fig. 10, *loc. cit.*), the canal may be seen as a depression along the lesser curvature. Similar figures are given without any comment by Broman (11), as pointed out by Lewis.

Keith and Jones (12) remark on a very definite canal running from the opening of the œsophagus to the pyloric antrum along the human lesser curvature. This they thought was probably for the conveyance of fluids. "Such a groove with vestigial ridges can certainly be detected in the human fœtal stomach."

It is, however, doubtful whether such appearances are due to more than the fact that the stomach develops from a very localised portion of the primitive foregut, this tube remaining more or less unchanged along the

lesser curvature. All gross evidence of this canal rapidly disappears, but Lewis believes that it persists long enough to influence the arrangement of the oblique muscle fibres. There can certainly be no physiological action, unless there be an anatomical mechanism underlying it, so that, although the canal has gone, it may well be that the muscular fibres are so disposed that they are able to produce a groove or gutter again at need.

Retzius (quoted by Lewis) supports the existence of the canal as follows:—

"The upper portion of the oblique fibres of the human stomach serves to form a trough along the lesser curvature, which, under the control of the motor nerves, becomes more or less closed; along this path possibly fluids and soft things, saliva, etc., may proceed directly from the œsophagus to the pars pylorica, passing by the cardiac portion."

Waldeyer (1), as mentioned above, describes a very definite "Weg" or "Strasse" along the lesser curvature which conveys ingesta chiefly because of the arrangement of the folds of mucous membrane (to be referred to shortly) and of the upright position of the organ. Of exactly how much value this observer believes the oblique muscle to be, it is difficult to judge from his writings, though Lewis quotes him as an adherent to this theory. Hasse and Strecker (13) have gone so far as to name the anterior and posterior lips of the gastric canal plica hepatica and plica aortica respectively, joined together above by the plica cardiaca. Their evidence, however, does not bear close investigation in the light of modern knowledge of the shape of the stomach, for they have based their description on the impressions made upon the stomach by neighbouring organs, and their figures of the viscus show a much indented and improbable organ. Strecker, however, in an independent paper, seems to favour the musculature rather than folds produced from without as a canalive agent. Kaufmann (10) is a strong upholder of the muscular theory, and believes that the oblique fibres are capable of temporarily converting the groove into a canal.

Ernst (15) has pointed out that the stomachs of people who have swallowed corrosive fluids show most destructive lesions along the lesser curvature.

Existing radiographic evidence of the gastric canal is to be found only indirectly, as workers in this subject appear to be quite ignorant of such a possibility. Barclay (16) figures bismuth entering the stomach and being closely confined to the lesser curvature (*loc. cit.*, fig. 15), and Gray (17) draws attention to the radiograms of Ribas y Ribas (18) as proof of the existence of the remains of the primitive foregut. These photographs (*q.v.*, Nos. 15–17) are certainly suggestive, but are open to criticism

(*vide infra*), as the bismuth may simply be taking the shortest route to the bottom of the stomach, towards which it is progressing in a uniform

FIG. 2.—Skiagram of the almost empty normal human stomach. A thin stream of bismuth occupies the position of the canalis gastricus at the lesser curvature. Note the essentially vertical position of the stomach, and the obliquity and narrowness of the terminal œsophagus. A peristaltic wave is coursing along the pars pylorica, involving its whole diameter.

stream. Hartung, in a very recent paper, says: "The first few mouthsful seem to follow in groove arrangements along the lesser curvature, called the 'Magenstrasse' by the Germans."

From the clinical side, most surgeons are familiar with what we may term selective vomiting, *e.g.* the vomiting of bile instead of the food which has just been taken. This is very puzzling, unless we credit the stomach with the power of cutting off a portion of its interior from the general cavity.

Evidence of the Present Investigation.

This will be best considered under two heads—

A. Radiographical.

B. Anatomical.

This is strictly the order in which the investigation was carried out, for had not the author been considerably encouraged by his X-ray findings he would hardly have attempted to find an anatomical mechanism which would explain the appearances.

A.—*Radiography.*

Some twenty-two normal people were investigated through the kindness of Dr Knox. The patients were screened whilst swallowing a mixture of bismuth oxychloride and milk of the consistency of thin cream. The first point was to find whether the fluid, as it entered the stomach, spread out over the walls or was confined to the lesser curvature. Judging by the extreme obliquity at which the œsophagus enters the stomach (see fig. 2), the former of these two possibilities would be expected. Such, however, is not the case. In eighteen out of the twenty-two cases (roughly 82 per cent.) the fluid was confined to the lesser curvature. In the other four cases it spread rapidly over the sides of the stomach, but these stomachs were atonic, though healthy—a combination by no means rare.

It is easy to watch the descent of the fluid by means of the fluorescent screen, but it is a difficult matter to obtain a satisfactory photograph, owing to the difficulty of judging the psychological moment at which to take the plate. One cannot use the screen and the photographic plate at the same time.[1] There were great variations in the time at which the fluid actually entered the stomach and then descended through its body. The variation in the time of entry is obviously due to the nervous control of the cardia (Cannon (20), *loc. cit.*, p. 34), for the time occupied in the traversing of the œsophagus is fairly constant. The time difference in the descent through the stomach is well known to radiographers, and usually ascribed to cohesion of its walls (Bythell and Barclay (21), *loc. cit.*,

[1] L. G. Cole has recently devised a cinematograph X-ray table by means of which this is possible. This marks a great advance, but is, of course, expensive. See "Roentgeno-cinematography of the Stomach and Cap," *Amer. Journ. Roentgenology*, March 1914.

p. 86; also Hertz), or difference in the specific gravity of the bismuth.[1] With this view I cannot agree, believing it to be more probably due to a neuro-

FIG. 3.—Skiagram of the almost empty normal human stomach. A column of bismuth is entering the stomach by the canalis gastricus. The incisura angularis is well shown. A deep wave of contraction involves the pars pylorica. Coin indicates umbilicus.

muscular mechanism controlling the action of the oblique muscle fibres—a point to be referred to later.[1] A few good photographs were obtained,

[1] I find that Brauening (22) suggests that there is an œsophageal reflex that increases tone in the gastric musculature and may delay descent. If we admit the existence of a gastric canal, this action becomes purposive.

and to three of these (figs. 2, 3, and 4) the reader is referred. I wish to call attention particularly to figs. 2 and 3, which are photos of the practically empty human stomach. Two mouthsful of the bismuth cream were given to map out the greater curvature at its lowest point, and the exposure made immediately after the patient had swallowed the third. It will be seen that a small quantity of bismuth is at the bottom of the stomach, a rather less quantity at the cardia, whilst joining the two together is a narrow stream of bismuth strictly confined to the lesser curvature. There are three possible explanations of these appearances:—

(1) That the fluid has fallen by gravity down the nearest wall, by the most direct path;

(2) That the stomach is tightly contracted down, so that its lumen is no larger than will allow of the passage of the bismuth in a thin stream;

(3) That it is lying in a physiological canal or gutter—the canalis gastricus.

That gravity plays an important part in the descent of the bismuth down the lesser curvature it would be foolish to deny. There are probably no peristaltic waves along this curvature (see figs. 2 and 8). The point at issue is whether the cream is falling down a specialised channel cut off from the remainder of the stomach, or is merely taking the shortest path to the bottom of that organ, as it would if led into an inert bag. The fact that there is a considerable quantity of cream held up at the cardia is strong evidence against this first theory. Had the whole of the fluid fallen to the bottom of the stomach, as it may be seen to be doing in Ribas y Ribas skiagrams, this explanation might have had more than a little of verisimilitude. But a quantity is so definitely shown in fig. 2 to be held up just below the cardiac orifice that such an explanation seems to me improbable.

The second possibility merits careful consideration. Hertz has described the normal empty stomach as being contracted down like a piece of small intestine, its cavity being potential only, and suitable for representation in linear fashion (*Quart. Journ. of Med.*, 1910, fig. 5). It might be argued on this view that figs. 2 and 3 simply show canalisation of the contracted viscus. With this view I am quite unable to agree, though his teaching has become more or less the standard one, and his drawings accepted for students by Waterston in the latest edition of Cunningham's *Anatomy* (*q.v.*, fig. 923). There are two great objections, however, to the Hertz doctrine. It is difficult to believe that the long smooth muscle lengths of the stomach are ever capable of such shortening as would be necessary to reduce its lumen to zero, however much they were rearranged (Müller (23)).

Perhaps the pyloric canal, the last two inches or so of the expulsive portion of the stomach and that most nearly approaching the small intestine in

FIG. 4.—The normal human stomach half full. The track by which the bismuth has entered is clearly seen at the lesser curvature. A few flakes of bismuth map out the greater curvature. Some of the bismuth had passed on into the small intestine before the cream was given.

calibre, can contract down to a state approximating to that assigned by Hertz to the whole stomach. One can well believe that the stomach has only a potential cavity, owing to approximation of the anterior and posterior walls. The writer wishes to be quite explicit about this. He

does not believe the stomach to be a flabby bag, with its walls in apposition, like the rubber hot-water-bottle stomach (so to say) of all but recent anatomy. Nor is fig. 5 quite satisfactory in showing a stomach of average outline *in vivo*. The normal lies somewhere about midway between this and the condition described by Hertz.

Further, in fig. 2 it will be noted that the bismuth descends excentric-

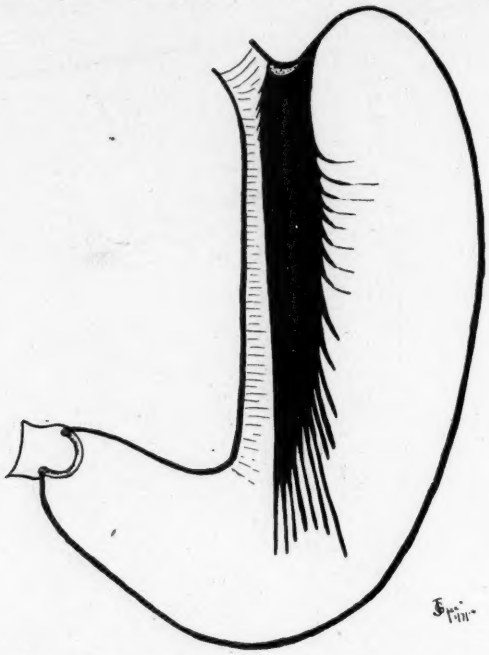

FIG. 5.—Diagram of the vertical portion of the oblique muscle of the stomach, which forms an inverted U over the viscus. By its contraction it can cut off a passage along the lesser curvature. (Camera-lucida drawing of stomach in its normal upright position.)

ally from the extreme left-hand margin of the top shadow, as if it was only at this point that there is a way of escape. If Hertz's theory were correct, all the shortening must occur towards the lesser curvature, so as to make excentric the lumen of the stomach. His diagrams (fig. 3, *Brit. Med. Journ.*, 28th Sept. 1912, and fig. 5, *Quart. Journ. of Med.*, July 1910) show that he has not thought this to be the case.

An attempt to prove the existence of the canal radiographically was made by pressure over the partly filled stomach, with doubtful result. (It

was thought that the bismuth might ascend it on such pressure.) But it seems to me very probable that the canal is only segregated by the stomach for a few seconds at a time when soft things are entering, so that this cannot be accepted as evidence against the existence of the canal.

The third possibility is that the stomach is making a co-ordinated effort to direct the fluid into a channel at its lesser curvature. This must be accomplished by means of specialised bands of muscle, and before this theory can be accepted it must be shown that there is in the stomach a mechanism capable of such an action. With this end in view, the writer proceeded to the second part of the investigation, and this is now put forward.

B.—*Anatomical.*

The well-known description of the gastric musculature by Birmingham (24) is of little or no value. For he had figured the stomach as a horizontal organ with fundus to the right and on the same level as the pylorus (*vide* Cunningham's *Anat.*, fig. 926, and *loc. cit.*), a belief in which he was joined by Willis (25) in 1674, and apparently also among others by Paterson (26) in 1913. Cunningham's (27) dissection (*loc. cit.*) by removal of the mucosa is very valuable, for here the stomach is drawn in its true vertical position. The writer investigated five human stomachs after the method of Cunningham, the stomachs first being hardened in formalin after having been arranged with the lesser curvature vertical and the fundus upwards (fig. 5). Reference to this figure shows the disposition of the inner or oblique coat. This runs vertically down the whole length of the body of the stomach. It is a narrow, flat band, coursing from the incisura cardiaca, which fold it produces, to the commencement of the pars pylorica. I have not found it turning round the incisura angularis to run towards the pylorus, as figured by Cunningham. The fibres are perpendicular, the outermost curving outwards and gradually becoming lost by mingling with the circular coat. The right margin of this muscle band is sharply defined, and has no deep connexions. It can be readily dissected up from the circular coat beneath it. This band forms an inverted letter U over the stomach. And it seems reasonable that by its contraction it will cause more or less of a cutting off of a canal along the lesser curvature.

From my own dissection of the horse's stomach (to which animal Professor Keith kindly called my attention) I was unable to find any muscle other than the oblique coat which could cut off a canal for fluids. The disposition of this muscle in this animal looks to be more unpromising for such an action than it does in the human, yet its physiological presence is undoubted.

It was not until my dissections were nearing completion that I became acquainted with the painstaking work of Forsell (28), who, for a different purpose, has correlated the musculature of the stomach with X-ray findings. This author attaches great importance to the oblique layer, which he figures as being arranged in definite muscle slings (fig. 6). This division appears to me rather didactic, for I have been unable to find anything which

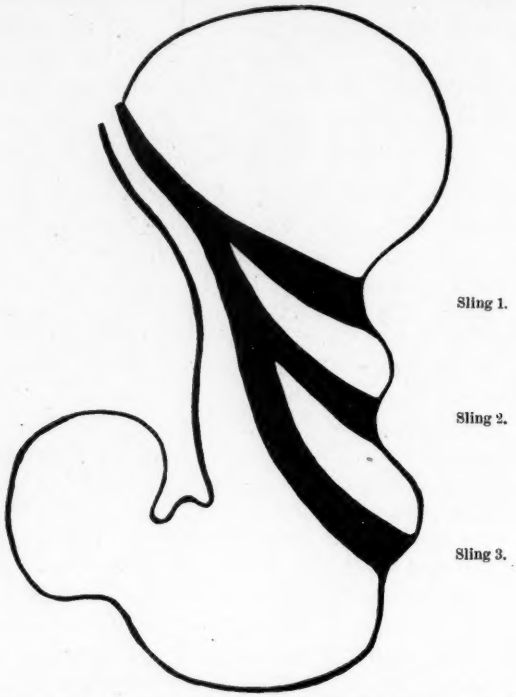

FIG. 6.—The oblique muscle of the stomach (vertical portion), to explain fig. 8, and draw attention to a muscle the importance of which has been greatly underestimated. Note the muscle slings. (After Forsell.)

distinguishes one band of this muscle from the rest of it; the whole forms one homogeneous sheet. However, Forsell does good service when he calls attention to the importance of the oblique coat and its relations to the circular. Thus, the bismuth which was so constantly held up just below the cardiac orifice (*e.g.* see fig. 2) is probably held there by contraction of the upper oblique fibres, whilst the canalis gastricus is shut off by contraction of the vertical parallel fibres (see fig. 5). This seems to me much

the most rational explanation, as a moderate shortening would be sufficient to produce both these effects. Whilst an excessive contraction would be needed of the circular fibres if they were the causal factors, such a cutting off is facilitated by the arrangement of the mucous membrane in the

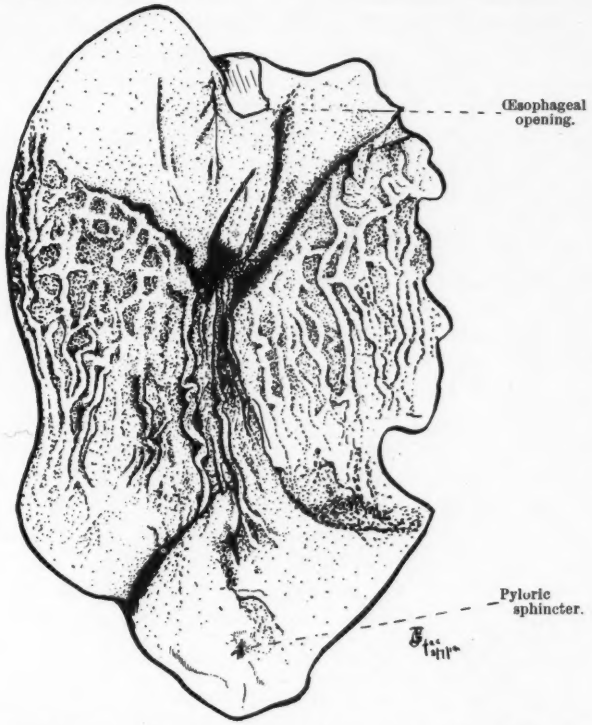

FIG. 7.—The human stomach cut open along the greater curvature almost to the pylorus, to show the mucous membrane. Note the arrangement of the longitudinal plicæ without anastomoses at the lesser curvature, compared with the network over the greater part of the body of the stomach. (Camera-lucida drawing.)

interior of the stomach, which lies in longitudinal folds along the lesser curvature (fig. 7). These folds, three or four in number, are very constant, and are limited to the lesser curvature. Over the rest of the stomach the folds are not so salient, and are joined together by low bridges, producing a stellate formation of variable completeness. Waldeyer attaches great importance to these folds as a help to fluids and "Flussigkeiten."

Comparison with the ruminant stomach on this point is helpful, for in the first two stomachs, where the food is destined to remain for some time the mucosa is deeply reticulated, muscle bands sometimes entering into the walls of the cells (*e.g.* camelidæ). In the psalterium (as its name implies) and the abomasus, from which the food is to make a rapid exit into the duodenum, the mucous membrane is arranged in longitudinal plicæ, so as to offer the least resistance to its outgoing, whilst at the same time increasing the glandular surface.

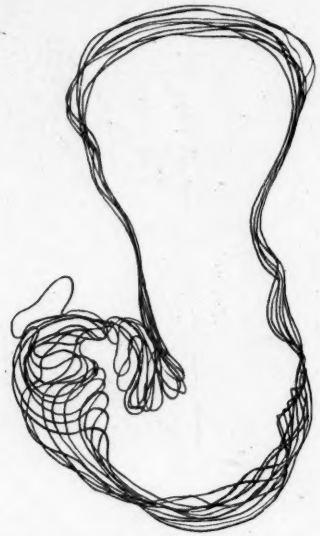

FIG. 8.—Superimposed tracings of twelve photographs of a single contraction phase of the human stomach. Note the great activity of the pars pylorica and greater curvature of the body of the stomach, compared with the absence of peristalsis along the lesser curvature as far as the incisura angularis. (After Kaestle, Rieder, and Rosenthal.)

Further proof of the specialisation of the lesser curvature of the pars cardiaca for some function other than that of slowly pressing the food out into the active pyloric portion may be found in the following observations:— There is a very marked difference in the action of the muscle along the lesser curvature as seen by X-rays, the change occurring at the incisura angularis. The whole diameter of the pars pylorica takes part in active peristaltic waves coursing towards the pylorus. It is, however, very rare to see any indentation of the lesser curvature in the pars cardiaca. In this portion the waves of contraction will be seen to involve the greater curva-

ture only. A reference to the well-known diagram of Kaestle, Rieder, and Rosenthal inserted as fig. 8 will make this clearer. The lesser curvature changes in position slightly, as indeed is to be expected in a viscus not rigidly fixed and subject to intrinsic muscular movements, but it does not change in shape. It would seem very probable from this alone that there is a fundamental difference in function between the lesser curvature in the two portions of the stomach, over and above the different general functions that the last are known to possess.

Conclusions.

A review has been made of the records of this subject so far as they are available to the author, whilst his own observations have been tried in the light of the knowledge so gained. It seems fair to deduce in conclusion that there is a canal along the lesser curvature of the human stomach which conveys fluids and soft things to the pars pylorica without their mingling with the more solid food in the pars cardiaca. It was shown that the X-ray findings were such as could be reasonably explained from the arrangement of the oblique musculature and the mucous membrane of the stomach. It is reasonable to suppose that this canal is the homologue of the well-known gastric canal of ruminants, whose first two saccular stomachs are homologous with the pars cardiaca of the human stomach. The indisputable epithelial canal present in the human fœtal stomach is its representative, and influences the arrangement of the oblique muscle coat, which has been shown to be capable in its turn of re-forming a canal at need. It is hoped that further confirmation or criticism may be obtained from radiographers, now that attention has been more specifically drawn to this subdivision of the stomach. It is high time that our views upon the musculature of this last underwent the same revision that our views upon the general shape and disposition of the stomach itself have undergone. For it is obviously illogical to remodel one's views on the general conformation of a viscus without at the same time recognising that the parts of which it is composed must be arranged somewhat differently from that which the old teachings had supposed. As for the actual shape of the stomach itself, fig. 2 represents to the author's mind the standard normal. But as Case remarks on this point, "I would as soon attempt to describe the normal colour of the hair, the normal colour of the eyes, the normal shape of the mouth and nose, etc." (30).

In conclusion, I have to express my indebtedness to a large number of people, but more especially to Dr Robert Knox for so kindly allowing me to use the Radiographical Department of the Cancer Hospital, Brompton, S.W., as if it were my own; to Dr Archibald Leitch for use of his labora-

tory at the same hospital; to Professor Arthur Keith for some valuable suggestions; and to my wife, Dr Gertrude Flumerfelt, for her valued help with the literature.

Summary.

1. Lewis, and Keith and Jones, have shown that there is an epithelial passage along the lesser curvature of the human fœtal stomach, such as could directly convey fluids to the pars pylorica. This is best named the canalis gastricus. It persists long enough to influence the arrangement of the oblique muscle fibres.

2. Many writers have brought forward evidence that such a canal persists in the human adult, and that it represents the well-known sulcus salivalis or sulcus œsophagus (canalis gastricus) of ruminants.

3. The writer by means of radiograms has confirmed these findings, and shows a thin fluid suspension of bismuth confined to the lesser curvature in 82 per cent. of cases examined.

4. Of the possible explanations of this fact it is shown that the most probable is that it is lying in the canalis gastricus.

5. The inner or oblique muscle coat of the stomach is arranged in such a manner that by its contraction it will cause a temporary cutting-off of a canal along the lesser curvature. And the mucous membrane lies in long ridges at this curvature in a manner conducive to such an action.

6. It is time that our views upon the arrangement of the musculature of the stomach were modified to suit our new views of its position, shape, and function.

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A RARE VASCULAR ANOMALY—OPENING OF THE UPPER LEFT PULMONARY VEIN INTO A PERSISTENT LEFT SUPERIOR VENA CAVA.

By T. B. JOHNSTON, M.B., Ch.B., *Lecturer on Anatomy, Edinburgh University.*

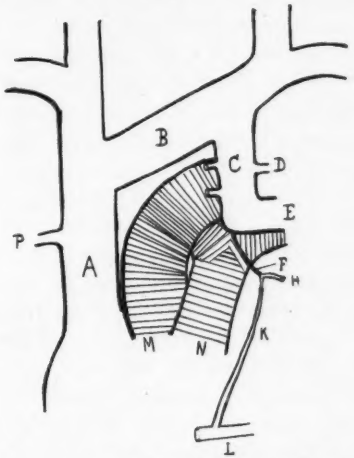
THE following vascular anomaly was found in the body of an adult male subject, dissected in the Anatomy Department of the University of Edinburgh. Unfortunately, nothing is known about the clinical history of the case, but the subject, who died from the inhalation of poisonous gases, was stated to be 56 years of age, and his muscular development was rather above the average. It may therefore be assumed that the anomaly to be described had had little effect on the health of the subject.

The condition of the great vessels of the thorax was, briefly, as follows The superior vena cava was normal in its mode of formation, in its course, and in its termination, but its lumen was rather greater than usual. This increase in size was attributable to the left innominate vein, which, constituted in the ordinary way, received a large ascending tributary at a point about half an inch from its commencement. When this anomalous vessel was traced downwards, it was found to cross the left side of the arch of the aorta, and, in front of the left pulmonary artery, it deviated to the left in order to enter the upper and anterior part of the hilus of the left lung. In the vertical part of its course, this vein was joined, on the right side, by mediastinal and thymic tributaries, and, on the left side, by the left superior intercostal vein. At the point where it turned to the left, its lower border received the upper attachment of the ligamentum venæ cavæ sinistræ. The latter descended in front of the left pulmonary artery, and, at the lower border of that vessel, it entered the fold of pericardium with which it is normally associated. On reaching the surface of the left atrium, the ligamentum venæ cavæ sinistræ became continuous with the upper end of the oblique vein of the left atrium, which coursed downwards and to the right on the posterior aspect of the left atrium, and terminated by joining the coronary sinus. At the point where the oblique vein and the ligamentum venæ cavæ sinistræ became continuous, a small vein arose, and, after a short course, opened into the left atrium in the neighbourhood of the orifice of the lower left pulmonary vein.

The pulmonary veins of the right side showed the usual arrangement, and they opened into the left atrium by two separate orifices.

The ligamentum arteriosum was not patent, and the aorta, the pulmonary artery, and the other thoracic blood-vessels showed nothing unusual.

Certain additional anomalies were present in the heart. The organ was definitely enlarged, and this increase in size affected, more particularly, the atria and their auricles. When the interior of the right atrium was examined, the condition of the interatrial septum at once attracted attention. The floor of the fossa ovalis was unusually thin, and it showed a number of small perforations. In addition, it was definitely redundant, and



A, superior vena cava; B, left innominate vein; C, left superior vena cava; D, left superior intercostal vein; E, vein issuing from upper and anterior part of hilus of left lung; F, ligamentum venæ cavæ sinistræ; H, small vein opening into left atrium; K, oblique vein of left atrium; L, coronary sinus; M, aorta; N, pulmonary artery; P, vena azygos.

it would appear to have bulged into the cavity of the left atrium during life. The limbus fossæ ovalis was well formed, but, in its upper and anterior part, it had failed to fuse with the floor of the fossa ovalis, and the handle of a knife could be passed upwards between the two into the left atrium. When the interatrial septum was examined from the left side, the orifice through which the instrument passed was readily seen. It possessed a sharp, slightly thickened, crescentic lower border, which was concave upwards, and in its neighbourhood numerous smaller openings occurred, giving this portion of the septum a somewhat fenestrated appearance. These openings were under cover of the limbus fossæ ovalis, which probably had a more or less perfect valve-like action, but the smaller orifices in the lower part of the septum were quite unprotected.

Another anomaly was present in the interior of the right atrium. The orifice of the superior vena cava was partially guarded by a valve, which consisted of a single semilunar cusp. The valve was situated on the anterior and right lateral aspects of the orifice. Its upper, attached, margin was convex upwards, and its lower, free, margin was straight; in its upper part the cusp showed several small perforations, similar to those often found in the valve of the inferior vena cava. The posterior extremity of its lower margin could be clearly traced down the posterior part of the right wall of the atrium, lying on the surface of the crista terminalis. Inferiorly, it became continuous with the valve of the inferior vena cava, which was also markedly fenestrated in appearance. The anterior or medial extremity of the valve of the superior vena cava could not be traced further.

Previously recorded cases of connexions between the pulmonary and the systemic veins are very few in number, and I have only been able to collect nine examples. Of these, all except two occurred on the right side; in two cases there was no opening in the interatrial septum. In none of the recorded cases is any mention made of an additional small vein opening into the left atrium; and in none was there any valve at the orifice of the superior vena cava.

The explanation of a connexion between the pulmonary and the systemic veins must depend on the view accepted for the development of the pulmonary veins. If one accepts the view, put forward by Flint (1) and others, that the pulmonary veins originate in the lungs and grow towards the heart, then it is quite clear that, under abnormal conditions, one of the pulmonary veins might meet and open into one of the systemic veins instead of into the left atrium. Such an explanation would account for the previously recorded cases, but it would leave unexplained the small vein opening into the left atrium in the present case.

On the other hand, Fedorow (2) has recently put forward the view that the pulmonary veins originate as an outgrowth from the sinus venosus and grow into the lungs. If this view is accepted, then the anomalous connexion between a pulmonary and a systemic vein is not so easy to explain.

It is known, however, that the bronchial veins, which normally terminate in the systemic veins, establish anastomoses with the pulmonary veins in the lungs. It may be suggested, therefore, that, in cases where a pulmonary vein either fails to develop or fails to reach the lung, one of these anastomosing channels becomes widely dilated, and the blood which should pass through a pulmonary vein into the left atrium passes through the anastomosis into a bronchial vein, and thus eventually reaches one of the systemic veins.

If this hypothesis is applied to the previously recorded cases, it would

appear that the pulmonary vein outgrowth from the sinus venosus had failed to break up into a sufficient number of smaller veins, *i.e.* in the previously recorded cases one of the pulmonary veins had failed to develop. In the present case the condition is slightly different. All four pulmonary veins have developed, as witnessed by the openings into the left atrium, but the upper vein of the left side, instead of reaching the left lung, met and opened into the left duct of Cuvier. It is therefore found connected with the oblique vein of the left atrium. As a result of this occurrence, the blood from the upper and anterior part of the left lung was compelled to find a new channel of return, and this was effected by the wide dilatation of an anastomosis with a bronchial vein which terminated in the left superior vena cava.

The view put forward that the small vein which opens into the left atrium and is connected to the upper end of the oblique vein is in reality the upper left pulmonary vein receives additional support from its intimate association with the ligamentum venæ cavæ sinistræ.

With reference to the anomalies in the heart itself, it is clear, since they do not occur in all the previously recorded cases, that they are not dependent on the vascular anomaly, but are simply additional signs of developmental arrest. In the upper and anterior part of the interatrial septum, the septum primum and the septum secundum have failed to fuse, and the foramen ovale secundum has persisted. The numerous smaller openings in the fossa ovalis suggest the possibility that the foramen ovale secundum may be formed by the fusion of a number of small perforations, and not in the way which is usually described.

The valve at the orifice of the superior vena cava is very similar to one described by Sir William Turner (3) in a case where the pulmonary veins and the interatrial septum were normal. It represents the persistence of the greater part of the right venous valve at the opening of the sinus venosus into the atrial chamber of the heart. It is possible that the part at the orifice of the superior vena cava may represent not only the upper extremity of the right venous valve, but also a portion of the septum spurium. This, however, is only a possibility, and no proof can be brought forward in its support.

I should like to thank Professor Robinson for granting me permission to describe this somewhat rare anomaly of the vascular system.

Note.—Since the above was written, I have had the opportunity of reading A. J. Brown's paper on "The Development of the Pulmonary Vein in the Domestic Cat," *Anat. Record*, vol. vii., No. 9. The conclusions at which he arrives are very similar to, although not identical with, the conclusions drawn in the present note.

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PRELIMINARY NOTE ON A DIARTHRODIAL ARTICULATION BETWEEN THE CLAVICLE AND THE CORACOID.

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The specimen consists of the shoulder-girdle of a man æt. 50, and shows on either side a diarthrodial articulation between the clavicle and the coracoid process. The condition is not only bilateral, but for all practical purposes symmetrical. Nothing whatever could be ascertained as to the man's previous history or occupation.

The only other abnormality noted was the presence, on each side, of a well-marked sternalis muscle.

Description of the Specimen.

A. *The Scapula.*—On the ventral aspect of the coracoid process, near its root, and at the site of the normal attachment of the trapezoid ligament, is an oval facet, the longest diameter of which is half an inch. This facet was covered by a firmly adherent and thick pad of fibro-cartilage.

B. *The Clavicle.*—This bone shows a clear demarcation into two parts, *i.e., an inner two-thirds,* well developed, and presenting a strong anterior convexity, and *an outer third,* relatively feebly developed, giving the appearance of a secondary buttress or girder, passing to the acromion process of the scapula.

At the junction of the two parts below and behind is a well-marked projection, at the site of the conoid tubercle. This projection presents an articular facet, which is directed downwards, backwards, and outwards, and which was covered by a firmly adherent disc of fibro-cartilage.

The joint so formed between the clavicle and the coracoid was surrounded by dense ligamentous and tendinous fibres, forming a capsule, and composed in great part of the coraco-clavicular ligament. This capsule was lined by synovial membrane, which was involuted as a number of folds into the joint by small pads of fatty tissue.

The sterno-clavicular and acromio-clavicular joints were normal.

Frequency of the Condition.

The only references which I have so far been able to find are:—

1. By Testut, who mentions having seen three cases: in a woman of 40, in a negro, and in a microcephalic idiot respectively.

2. By Sir Arbuthnot Lane, who refers to the condition as being common, though no details are given.

Etiology of the Condition.

There are, I think, two possible views. Firstly, the condition may be a congenital one. Secondly, it may be acquired; and Sir Arbuthnot Lane's view is that in individuals who habitually carry heavy weights on the head or trunk, which require the arms to keep them in position, the shoulder joints are maintained in a position of extreme flexion. The scapula is thus fixed on the clavicle by a form of locking of the coracoid and clavicle, and this is assisted by the pressure exerted by the weight carried.

Sir Arbuthnot Lane, indeed, suggests the use of this position in breaking down adhesions round the shoulder joint, and he believes that the continued apposition of the bones leads to the formation of a diarthrodial joint. He considers the condition to be an expression of the same factor which leads to the divorce of the tendon of the pectoralis minor as the coraco-humeral ligament.

As far as I am able to judge, Lane's cases were all unilateral, and the articulation was nearer to the tip of the coracoid than in the present example. He describes, however, an articulation as occurring further back in shoemakers.

It is interesting to note that a similar articulation may occur between the inner end of the clavicle and the first rib, and also that, instead of a definite diarthrodial articulation between the coracoid and clavicle, we may get deposits of cartilage in the trapezoid ligament, or in the outer portion of the subclavius muscle.

I would venture to suggest that with regard to this specimen the only rational explanation is that the condition is congenital.

This, I think, is supported by the condition being bilateral, and by its being apparently much better marked than in any case previously reported. It is somewhat difficult to imagine it as a result of weight-bearing, which would only be likely to date from or about the attainment of the adult condition.

Testut's cases, I hold, also support this view. The alteration in the

clavicle is, I think, particularly interesting, in the light of recent views as to the ossification of the bone from two primary centres, and as to its morphology from the point of view of the occurrence of cranio-cleido-dysostosis.

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MANIFESTATION OF OCCIPITAL VERTEBRÆ, AND FUSION OF THE ATLAS WITH THE OCCIPITAL BONE.

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THE significance of variations in the occipito-atlantal and other regions of the vertebral column has within the last ten or fifteen years received a very considerable amount of attention, and it is with the view of carrying on this study one stage farther that the authors of this memoir have been drawn into this fascinating field of phylogenetic and ontogenetic research.

The two first specimens which we shall describe, "Manifestation of an Occipital Vertebra," are an example of a variation which was formerly described under the name of "pro-atlas," as it was believed that an additional vertebra was interpolated between the atlas and the occipital bone, and that this additional bone had become more or less completely incorporated with the latter. According to Kollmann, Swjetschnikow, Macalister, Elliot-Smith, and other of the more recent anatomists, however, the condition is due to a partial liberation of one of the vertebral elements which normally enter into the composition of the occipital bone, and ought not to be regarded as an additional vertebra.

I.—MANIFESTATION OF OCCIPITAL VERTEBRA.

This specimen was found in a disarticulated skull of a young subject in whom fusion of the occipital bone with the sphenoid had not yet occurred.

On the under surface of the occipital bone (fig. 1) is seen in outline what appear to be the posterior and anterior arches, the lateral masses, and the left transverse process of an atlas. On critical examination, however, it is to be noted that there is no facet for the odontoid process of the epistropheus. Moreover, the articular surfaces, which are oval in outline and converge anteriorly, are directed laterally and downward, resembling occipital condyles rather than the inferior articular surfaces on the under aspect of the lateral masses of an atlas. The articular surfaces are pitted and rough, and look as if epiphyseal cartilages had been separated by maceration. The transverse process on the right side is absent, while on the left it is well developed and separated from the jugular process of the

occipital bone, which lies in front and lateral to it. The transverse process on the left side shows no foramen for the passage of the vertebral artery. A large canal is, however, present on the left side of the foramen magnum which, when viewed from the cranial aspect, is seen to be distinct from the canal for the hypoglossal nerve (anterior condylar). On the external surface, these two canals open close together at the bottom of a depression, which may be called the anterior condylar fossa.

The canal for the hypoglossal nerve is subdivided into two by a spicule of bone. The lower large canal, which lies posterior to the hypoglossal

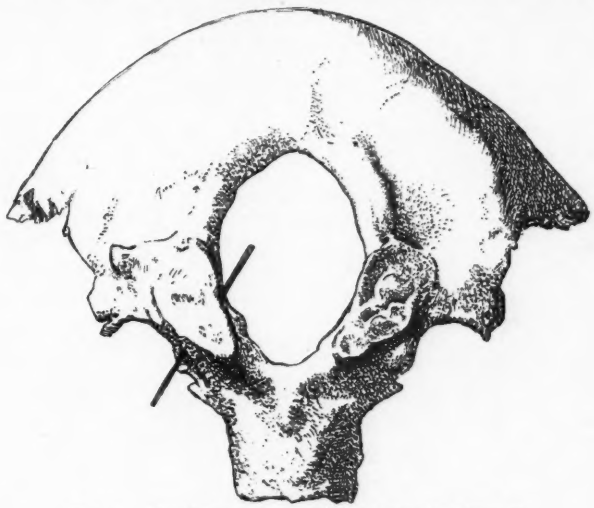

FIG. 1.—Manifestation of occipital vertebra (specimen 1).

foramen, is of sufficient size to have transmitted the vertebral artery; from its direction, however (see fig. 6), we infer that a vein passed through the foramen, and that the artery passed through the foramen magnum, after having passed between the posterior arch of the atlas and the occipital bone in the normal situation.[1]

[1] The vertebral artery, however, has been known to have passed through the anterior condylar foramen, or a large branch which will take the place of the vertebral artery may pass through the foramen; for example, a case described by N. Batuzeff (*Anat. Anz.*, May 1889) in which the basilar artery was absent, but was replaced by a vessel arising from the internal carotid artery, a short distance before this vessel entered the carotid canal. This abnormal branch entered the skull through the left anterior condylar foramen, and, having gained the basilar process of the occipital bone, gave off the usual branches of the basilar trunk; both vertebral arteries were atrophied.

In a second case described by Elliot-Smith (10), the vertebral artery passed through the anterior condylar foramen in a very remarkable and extreme case of assimilation of the

On the right side there are also two foramina. The upper on this side is the larger. It is not subdivided, and presumably both divisions of the hypoglossal nerve would have passed through the upper foramen, and the lower would have served for the transmission of a vein. As on the left side, both canals open at the bottom of an anterior condylar fossa.

On each side there is a large posterior condylar foramen, which opens on the cranial aspect of the bone into the groove for the transverse sinus.

The muscular markings and ridges on the nuchal portion of the bone are indistinct, the superior and middle nuchal lines, the external occipital crest, and the external occipital protuberance being only with difficulty distinguishable. The intra-cranial surface of the squamous portion of the bone shows marked asymmetry, the right cerebral fossa is much smaller than the left, and the left cerebellar fossa is smaller than the right, indicating that the right cerebral and left cerebellar hemispheres were imperfectly developed.

The sagittal sinus is continuous with the right transverse sinus. This lies at a higher level and is considerably larger than the left.

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atlas vertebra with the occipital. These cases may be readily explained by a reference to the early stages of development of this artery in the embryo.

Normally, a series of somatic segmental arteries are given off from the right and left dorsal aortæ. These are afterwards united in the cervical region, by a longitudinal vessel formed by intersegmental anastomoses situated between the costal elements and the transverse processes of the cervical vertebræ. The longitudinal vessel anastomoses in front with the posterior branch of the primitive cerebral artery, and forms with it a trunk called the vertebro-cerebral artery. The first somatic segmental artery, with its dorsal branch, accompanies the twelfth cranial nerve, and is known as the hypoglossal artery; the seventh persists as the first part of the subclavian and origin of the vertebral artery. The hypoglossal artery and the first six somatic arteries in the cervical region normally disappear. The longitudinal intersegmental vessel persists as the cervical portion of the vertebral artery, which is continuous below with the persistent seventh dorsal somatic artery, but has now lost its connexion through the anterior somatic arteries with that part of the dorsal aorta which forms the internal carotid artery.

Occasionally, however, the vertebral artery may arise from the internal carotid artery near the base of the skull, and, as in the case described by Batuzeff, pass through the anterior condylar foramen; or it may arise in the normal way from the subclavian artery, but instead of accompanying the first cervical nerve, pass with the hypoglossal nerve through the anterior condylar foramen. These cases are obviously due to a persistence of the hypoglossal artery.

The vertebral artery also has been known to be pierced by one of the rootlets of the hypoglossal nerve (J. W. Ogle). This is due to the persistence of the anastomosis which is normally formed between and around the fila of the hypoglossal nerve. In a human embryo of 10 mm. length, a series of segmental vessels are seen to pass from the vertebro-cerebral artery, in a dorso-lateral direction, over the side of the medulla spinalis to a longitudinal anastomosing vessel lying between the rootlets of the hypoglossal and accessory nerves. These segmental vessels pass between the rootlets of the hypoglossal nerve and between the hypoglossal and suboccipital nerves. Normally, the artery which courses ventrally between the hypoglossal and the first cervical nerves persists as the terminal portion of the vertebral artery. It represents the spinal branch of the dorsal division of a somatic segmental artery, with a preneural subdivision. This unites with a similar branch of the opposite side to form the basilar artery. In cases of complete fusion of the posterior arch of the atlas with the occipital bone, and in which there is no foramen for the vertebral artery between these bones, this vessel will have to pass either below the atlas, between it and the epistropheus, or through the occipital bone. In cases of manifestation of an occipital vertebra, the vessel usually passes between the atlas and the occipital bone. In rare instances, however, it passes through the occipital bone, either in a special canal or through the hypoglossal foramen.

II.—Manifestation of Occipital Vertebra.

This specimen occurred in a Gond skull belonging to Professor David Waterston, in the Anatomical Museum at King's College.

The indications of the occipital vertebra (fig. 2) are not so complete as in the previous case. The basal portion of the posterior arch is quite

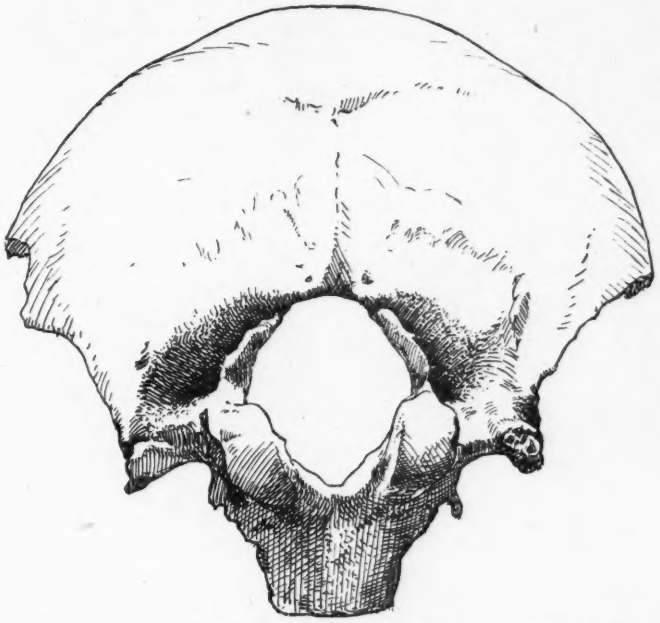

Fig. 2.—Partial liberation of occipital vertebra (specimen 2 (Gond skull)).

distinct on each side; the two halves of the arch, however, do not unite behind. Indications of transverse processes are present on both sides. On the under aspect of the right, the surface of the bone is rough, and appears as though a projection had been broken off.

The condyles and anterior margin of the foramen magnum do not differ markedly from the normal, and there is no facet for the odontoid process of the epistropheus.

A posterior condylar foramen is present on each side. The anterior condylar foramen is subdivided by a spicule of bone on both sides.

The skull in other respects appears to be quite normal, the muscular markings being well developed.

III.—An Atlas Vertebra fused with the Occipital Bone.

The anterior and posterior arches, and the lateral masses of the atlas, are united by bone with the under surface of the occipital (fig. 3). The transverse processes are free on both sides. On the right side the tip of the transverse process is in contact with the occipital bone, behind the jugular process, but is not fused with it. On the left side the transverse process of the atlas is separated from the occipital bone by about three

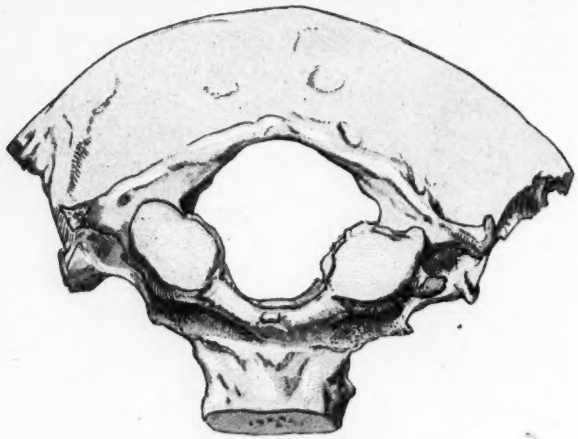

Fig. 3.—Atlas fused with occipital bone (specimen 3).

millimetres. The atlas does not differ very markedly in general appearance from the normal bone. The costal element of the transverse process is, however, rudimentary on both sides, especially the left, where it is represented by a mere spicule of bone situated in front of the groove for the vertebral artery.

At the base of the true transverse process there is on each side a small foramen, which probably served for the transmission of a vein.

A canal between the posterior arch of the atlas and the occipital bone for the vertebral artery is present on each side. On the right side a small groove is present on the posterior arch of the atlas, within this canal, for the trunk and posterior division of the suboccipital nerve.

A posterior condylar foramen is present on each side, which opens internally medial to the groove for the transverse sinus.

On both sides there is a groove for the occipital venous sinus, which on the right side is larger than that for the transverse sinus; the groove for the occipital sinus lies immediately lateral to the posterior condylar foramen, and the posterior condylar vein would thus have opened into the occipital sinus, instead of into the transverse sinus.

On the left side there is a smooth, walled, rounded hollow, formed at the bend of the transverse sinus and just below the tuberculum jugulare, which would probably have lodged a diverticulum from the transverse sinus.

On the right side there is a similar smooth, walled recess, but lateral to the groove for the transverse sinus, and separated from it by some rough bone. This is an air sinus, which is completed by articulation with the temporal bone.

The canalis hypoglossi (anterior condylar foramen) is partially subdivided on the left side; there is no indication of subdivision on the right. The bone overlying the canal is more slender than normal. There is a certain degree of asymmetry present, the left transverse process of the atlas being on a lower level than the right, and the posterior tubercle of the atlas being slightly to the left of the occipital crest. There is also a considerable downgrowth of bone on each side, lateral to the insertion of M. rectus capitis posterior major.

On examining the intra-cranial surface of the squamous portion of the occipital bone, it will be noticed that the groove for the transverse sinus of the left side is larger than that of the right. The groove for the sagittal or superior longitudinal sinus appears to be more directly continuous with that for the right occipital sinus than with either of the transverse sinuses.

IV.—Combination of Fusion of the Atlas with Manifestation of Occipital Vertebra, associated with the Presence of Cervical Ribs.

This is a specimen which one of us exhibited at the meeting of the Anatomical Section of the British Medical Association at Sheffield in 1908.

The specimen occurred in a female subject aged 86 which was dissected at the Middlesex Hospital.

Round the margin of the foramen magnum are indications of lateral masses, anterior and posterior arches, and the transverse processes of an occipital vertebra.

The anterior arch bears a facet directed downwards and backwards for the tip of the odontoid process of the epistropheus.

The transverse processes present no foramen for the vertebral artery, and are directed downwards and laterally. The right bears a facet on its under surface for articulation with the transverse process of the atlas. The left is fused with the corresponding transverse process of the atlas.

The anterior condylar foramen is subdivided on the right side, and single on the left.

Below the basilar process of the occipital bone there is a distinct groove, seen on both the intra- and extra-cranial aspects, marking off the anterior arch of the occipital vertebra from the occipital bone.

There is also a small tubercle on the anterior arch of the occipital vertebra, presumably for the attachment of M. longus capitis.

The atlas has the normal appearance of the first cervical vertebra, but differs in the following respects: the anterior arch is slightly hollowed out for the reception of the odontoid process, but there is no distinct facet.

The bone is fused with the occipital vertebra by the left transverse

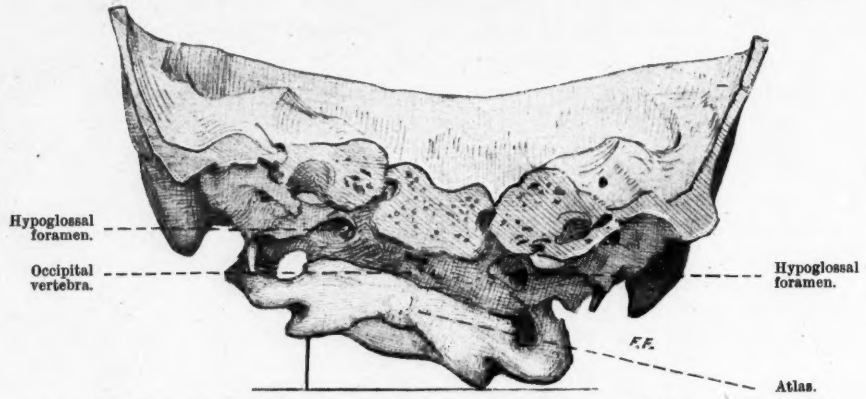

FIG. 4.—Specimen in which the atlas is fused with a partially liberated occipital vertebra. In the same subject a cervical rib was present on each side.

process and superior articular facet of the lateral mass. The right transverse process and superior articular process are in contact, but not fused with the occipital vertebra, a cleft-like space intervening between the paracondylar or transverse process of the occipital vertebra and the transverse process of the atlas, and also between the right condyle of the occipital vertebra and the superior articular facet of the atlas. The anterior and posterior arches are free.

The atlas is placed very obliquely, with relation to the base of the skull, and, like the specimen previously described, the left transverse process is considerably lower than the right. The transverse process on both sides is enlarged in an upward and backward direction to meet the transverse process of the occipital vertebra.

In the same subject a rudimentary cervical rib was present on each

side, which will be described in a separate paper, and a persistent foramen of Huschke was present in each tympanic plate.

In contrasting these two varieties, the points which we would lay most stress upon are the following :—

Manifestation of Occipital Vertebra.	Fusion of Atlas with Occipital.
Condyles oval in outline ; convex ; converge anteriorly ; surfaces directed downwards and laterally ; slight constriction separating anterior from posterior part of condyle. The condyles encroach only slightly, or not at all, on the foramen magnum.	Inferior articular facets nearly circular in outline ; slightly concave ; directed downwards and medially. The lateral masses encroach considerably on the foramen magnum. Cases, however, in which the atlas has fused with the occipital bone sometimes show a rounding off of the inferior articular facets, so that they may resemble the condyles of the occipital bone. This is due to the movements of flexion and extension of the head being transferred from the occipito-atlantal articulation to the joints between the atlas and the axis.
The anterior arch usually has no facet for the "dens epistropheus." In rare cases, however, a third occipital condyle may be developed on an "arcus præbasi-occipitalis" ("Manifestation des Occipital Wirbels," Schumacher, *Anat. Anz.*, Bd. xxxi. S. 153 ; and fig. 5, specimen 622·1, Museum of Royal College of Surgeons, England). The anterior arch is usually completely fused with the occipital bone.	The anterior arch usually has a facet for the odontoid process of the axis (dens epistropheus). There is usually an anterior tubercle for the attachment of the M. longus capitis. The anterior arch is frequently separated by a gap from the anterior margin of the foramen magnum.
Posterior arch not so wide as that of the atlas, and less distinctly marked off from the occipital bone. Usually no gap between it and the occipital. No canal for vertebral artery and suboccipital nerve between the posterior arch and the occipital bone. A groove is sometimes present on the under surface of the bone for the vertebral artery, immediately behind the condyles.	Posterior arch wider, forming an arc of a circle, the centre of which would be near the pharyngeal tubercle. The posterior arch is separated from the occipital bone by a canal for the vertebral artery and suboccipital nerve, or there is a distinct gap between the posterior arch and the occipital bone, with a groove on the former, as in the normal bone.
Transverse process as a rule presents no foramen for the vertebral artery, and is less separated from the occipital bone.	Transverse process frequently free, and pierced by canal for vertebral artery. Costal element may, however, be rudimentary, in which case a groove for the artery may usually be recognised in front of the true transverse process ; it may be united or articulate with the occipital bone by means of a paroccipital process.

Although the distinguishing points we have given above are usually sufficient to distinguish manifestation of occipital vertebra from fusion of atlas, exceptions sometimes occur which render the distinction difficult.

Thus, in a specimen described by J. Kollmann as "manifestation of an

occipital vertebra," a third or median condyle was present on an arch at the anterior margin of the foramen magnum, and a well-marked anterior tubercle was also present.

Another anomalous case is described by the late D. J. Cunningham as "manifestation of an occipital vertebra." This was considered by Professor Kollmann to be a high degree of assimilation of the atlas with the occipital bone. In this specimen there was no facet on the anterior arch, the articular facets on the under surface of the bone were convex, and there was no large foramen in the transverse process.

Farther, there was no canal between the posterior arch and the occipital bone for the vertebral artery and suboccipital nerve.

Notwithstanding these important points in favour of "manifestation of occipital vertebra," Professor Kollmann considers that Cunningham was mistaken in supposing this specimen was an example of manifestation of occipital vertebra, basing his opinion chiefly on the shape of the inferior articular facets. Professor Elliot-Smith, at a meeting of the Anatomical Section of the British Medical Association in July 1908, in commenting upon Kollmann's article, was disposed to agree with Professor Cunningham, but cites a case of his own in which the vertebral artery of the right side passed upwards in front of the transverse process to an anterior condylar fossa, and from thence turned medially through the occipital bone so as to open on the side of the foramen magnum below the *canalis hypoglossi*. Moreover, there was a facet on the anterior arch for the odontoid process of the axis, and, judging from the figure, this was directed downwards, and would have been supplementary to the facet on the anterior arch of the true atlas or first cervical vertebra.

Thus, a facet on the anterior margin of the foramen magnum, although in favour of fusion of the atlas with the occipital bone, may be present in a genuine case of manifestation of an occipital vertebra, as in cases previously mentioned, described by Schumacher (20), and specimen 621·1, Museum of Royal College of Surgeons, England (fig. 5). The odontoid process of the epistropheus would therefore in these cases have presented two facets, one at its tip for the third occipital condyle, and one on its anterior surface for the arch of the atlas. With regard to the foramen on the left side of the foramen magnum in the specimen that we have described (fig. 1 and fig. 6, B), it is difficult to say whether it would have transmitted the vertebral artery or the vein which usually accompanies the hypoglossal nerve.

A shallow groove within the foramen magnum, leading up to the canal from behind, appears to be in favour of the vessel being a vein, more especially as a similar groove leads up to the lower of the two foramina on the right side.

Farther, the direction of the canal from the intra-cranial aspect of the foramen magnum is forwards and laterally (fig. 6, B), whereas in a canal which would have transmitted the vertebral artery, the direction from the extra-cranial aspect would be medial, and then forward in a curved direction to the basilar process of the occipital bone (fig. 6, A). Moreover, the canal for the vertebral artery lies behind the superior articular process of the atlas.

The composite nature of the occipital bone is indicated by a study of

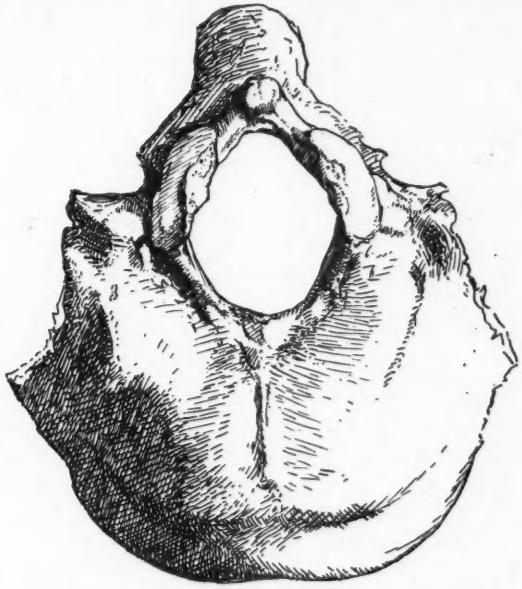

FIG. 5.—Manifestation of occipital vertebra.

the hypoglossal nerve, and the cranio-vertebral skeleton of the lower vertebrates, and especially in the dipnoi and certain fishes.

The hypoglossal nerve is generally believed to represent one or more of the anterior spinal nerves, and its transformation into a cerebral nerve can be traced in passing through the vertebrate series. The hypoglossal nerve "in some fishes and in all amphibia does not pass through the cranial wall, and is a true spinal nerve. In most fishes, and in the dipnoi, its inclusion within the skull can be seen to be due to a gradual assimilation of the anterior part of the vertebral column with the skull. In protopterus the hypoglossal nerve has two dorsal roots, each provided

with a ganglion" (*Comp. Anat. of Vertebrates*, Wiedersheim and Parker, p. 188).

Moreover, an examination of the basis cranii and rootlets of the hypoglossal nerve in young embryos gives further indications of the composite character of the occipital bone. In human embryos, for example, between 6 and 10 mm. length (see fig. 7) the rootlets of the hypoglossal nerve may be seen passing downwards from the medulla spinalis through what appears to be unsegmented mesenchyme. They are arranged in four or five groups, which converge to form two main trunks before finally joining in a single trunk. Medial to them are seen minute arteries, which are arranged in

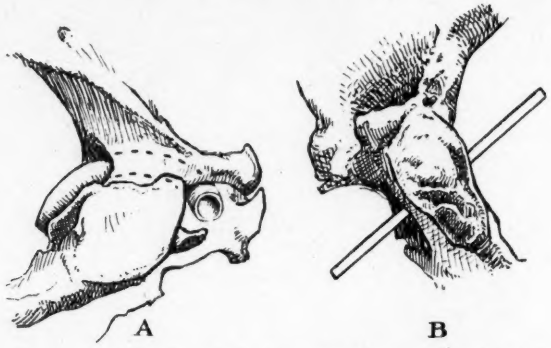

FIG. 6, A.—Assimilation of atlas with occipital bone (specimen 3), showing the curve and direction of the canal for the vertebral artery. B.—Manifestation of occipital vertebra (specimen 1), showing the direction of the canal below the anterior condylar foramen which presumably transmitted a vein.

series corresponding to the rootlets of the hypoglossal nerve. These vessels are probably intersegmental in nature, and pass between the vertebrocerebral artery and a longitudinal trunk lying lateral to the rootlets of the hypoglossal nerve; like the rootlets of the hypoglossal, they are four or five in number on each side. They correspond to the intervals between the rootlets of the hypoglossal nerve, and between the latter and the suboccipital nerve; in the specimen figured they are five in number.

Froriep (11) believes that the occipital region in the human subject is formed by the fusion of four rudimentary vertebræ, corresponding to three primary roots of the hypoglossal nerve. Of these four, only the posterior is at all independent; its development in the early stages resembles that of the vertebræ, and loses its identity only when fused with the parts in front of it (*Quain's Anatomy*, vol. i.: *Embryology*, T. H. Bryce, p. 255 (4)).

The partial independence of the last occipital vertebra has also been demonstrated by Weiss (23) in the white rat, who not only proves the existence of posterior and anterior arches of a last occipital vertebra, but also the presence of an independent mass of dense mesodermal tissue, forming the anterior part of the odontoid process of the epistropheus.

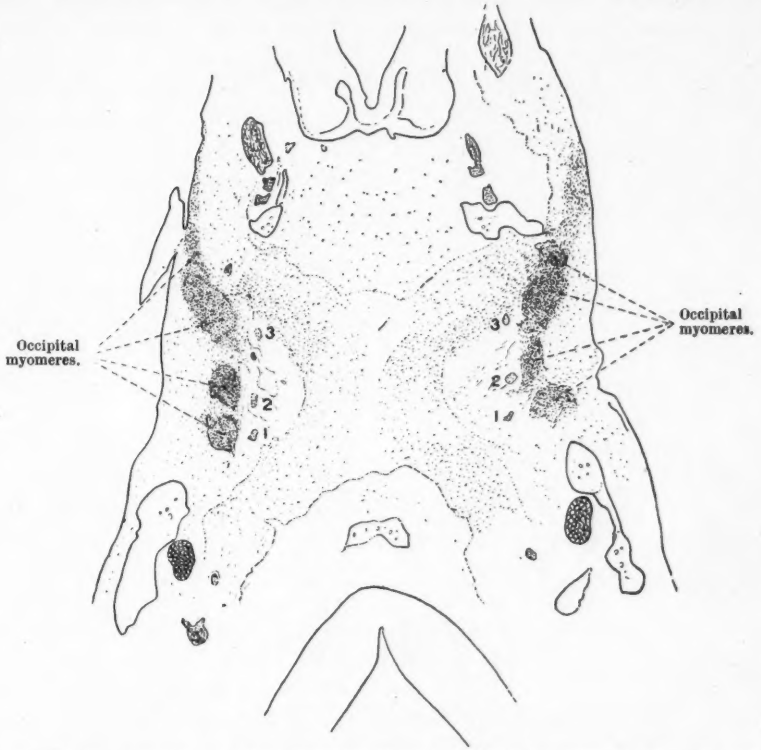

FIG. 7.—Transverse section of a human embryo (6 mm.), showing four occipital myomeres medial to which are the rootlets of the hypoglossal nerve. (From a specimen belonging to Professor D. Waterston.)

The odontoid process consists, therefore, in the white rat, of a basal portion, corresponding to the body of the atlas, and an apical portion which represents the body of a pro-atlas or last occipital vertebra.

In the human subject the relation of the transverse ligament of the atlas and the alar occipito-odontoid ligaments (check) to the base and tip of the odontoid process are confirmatory with regard to this view.

The serial homology of these ligaments was pointed out many years ago by J. Bland-Sutton (3) in his treatise on the Nature and Morphology of Ligaments, where he describes the transverse and check ligaments as being "repetitions of the posterior conjugal ligament" which connects the heads of the ribs behind the intervertebral discs in the thoracic region.

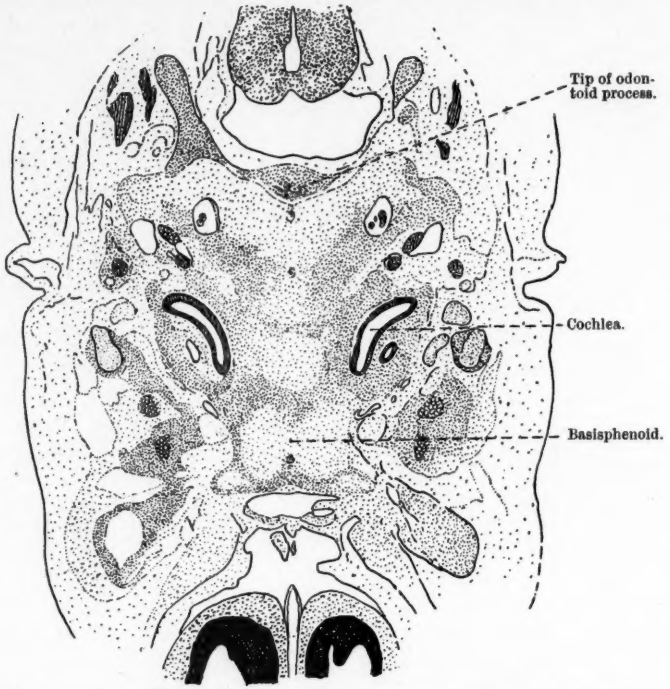

FIG. 8.—Horizontal section through the base of the chondro-cranium of a human embryo (22 mm.), showing swellings of the notochord at the tip of the odontoid process, and in the occipital region of the basicranial axis. The light areas represent areas of chondrification; these are separated by more deeply stained bands which lie between the cartilaginous centre in the position of intervertebral discs. (From a specimen belonging to Professor D. Waterston.)

Our observations on human embryos confirm Froriep's and Weiss's views with regard to the composite nature of the occipital bone in lower vertebrates. Fig. 7, which is a drawing from a transverse section of a 6 mm. human embryo belonging to Professor D. Waterston, shows indications of four occipital myomeres with intersegmental vessels, and three main groups of the rootlets of the hypoglossal nerve. These

latter separate four more deeply stained areas which correspond to occipital sclerotomes.

At a later stage, as seen in fig. 8, drawn from a transverse section of a 22 mm human embryo, also the property of Professor D. Waterston, it will be noticed that in the occipito-sphenoid plate there are four lightly stained areas of chondrification. The anterior of these represents the basisphenoid, and the termination of the notochord is seen within it. Behind this, in the occipital portion of the plate, three areas of chondrification, separated by two darkly stained bands, are visible. One of these bands lies at the level of the first turn of the cochlea. The next shows in its centre a swelling of

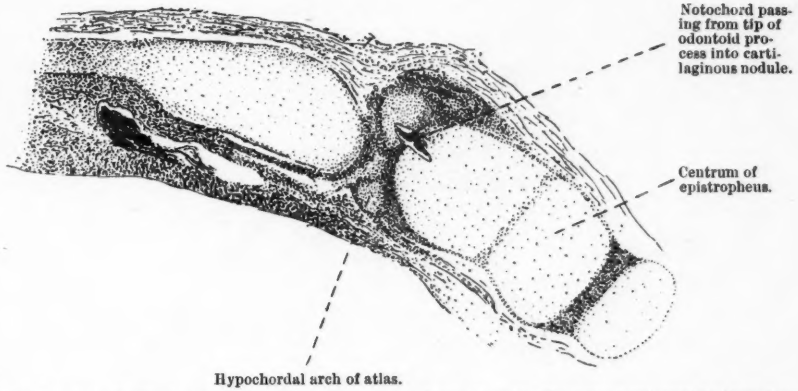
Notochord passing from tip of odontoid process into cartilaginous nodule.
Centrum of epistropheus.
Hypochordal arch of atlas.

FIG. 9.—Longitudinal section of a 16 mm. human embryo, showing the notochord passing from the tip of the odontoid process into a cartilaginous nodule representing the centrum of a last occipital vertebra or pro-atlas. Ventrally to this is seen a section through the hypochordal arch of the atlas.

the notochord. A second swelling of the notochord is seen at the anterior margin of the foramen magnum. The occipital plate therefore appears to be formed from three centres of chondrification, which afterwards fuse with one another, and with the basisphenoid, to form the continuous occipito-sphenoid cartilage seen in later stages.

The cartilaginous centre of the body of a last occipital vertebra, or pro-atlas, is sometimes developed in the human embryo, as is seen in fig. 9 and fig. 10. It is situated in front of the odontoid process of the epistropheus, and is traversed by the notochord. Fig. 9 is a drawing of a sagittal longitudinal section through the occipito-cervical region of a 16 mm. human embryo, belonging to Professor Waterston, and fig. 10 is an idealised mesial section reconstructed from this and neighbouring sections of the same series.

A slight constriction and a zone of closely packed nuclei show the line of demarcation between the body of the epistropheus and the dens. The hypochordal arch of the atlas vertebra is seen in the angular interval between the dens and occipital cartilage. There is in this specimen no clear indication of a hypochordal arch of the last occipital vertebra.

On examining other human embryos cut in longitudinal and transverse serial sections, we were unable to find another cartilaginous centrum so distinctly differentiated from the body of the atlas as the one figured above; nor have we found one in the embryos of lower mammals which we have ex-

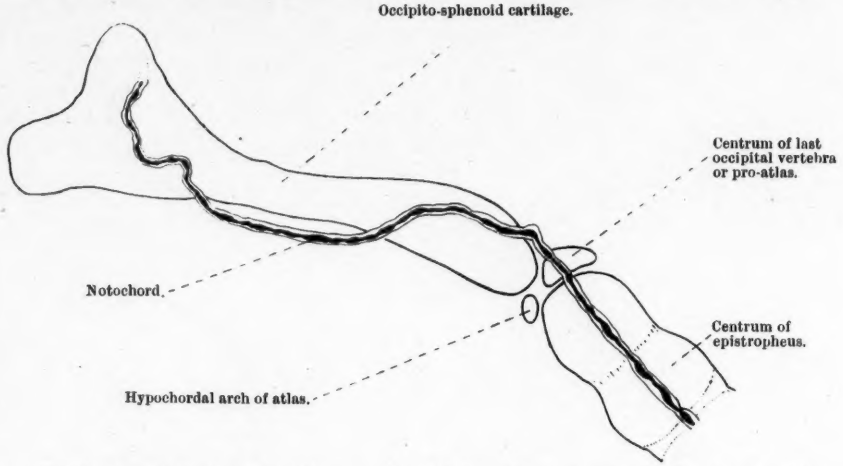

FIG. 10.—An idealised medial section, reconstructed from the section shown in fig. 9 and neighbouring sections of the same embryo, showing the relations of the notochord to the epistropheus, the centrum of the last occipital vertebra or pro-atlas, and the occipito-sphenoid cartilage.

amined, viz., carnivores (dog, cat) and rodents (mouse, guinea-pig, rabbit). Weiss, as we have previously mentioned, has, however, demonstrated in the white rat that the body of a post-occipital vertebra fuses with the body of the atlas, and forms the point of the dens epistropheus. On the question whether this rudiment should be regarded as the body of a true occipital vertebra, or as a pro-atlas, he does not, however, express a definite opinion.

If a median sagittal section be made through an axis vertebra, it will be noted that the height of the dens and body taken together is greater than the bodies of two cervical vertebræ and an intervertebral fibro-cartilage. It is in fact nearly equal in height to the bodies of three cervical vertebræ. There is also in young bones a lenticular disc of cartilage between the body of the epistropheus and the dens. This disc

is situated near the junction of the lower third with the upper two-thirds of the bone. Moreover, the apical portion of the bone which gives attachment to the alar or lateral occipito-odontoid ligaments is denser in structure than the lower cancellous portion of the bone, and is sometimes marked off from the body of the atlas by a thin plate of compact bone. It appears to us, therefore, that the dens is formed from two centra, in addition to the centrum of the epistropheus: a lower, the body of the atlas; an upper, the body of a pro-atlas or last occipital vertebra. In exceptional cases the latter is represented in the embryo by a separate centre of chondrification. Normally, however, a single cartilaginous centre represents the two elements. The main portion of the dens, including a part of the apex, is ossified from the two primary ossific centres. The extreme tip of the odontoid process is, however, ossified by a separate centre, which appears about the third year. This is considerably earlier than the date of appearance of the secondary or epiphyseal centres of the bodies of the vertebræ, which is stated to be about the sixteenth year. It appears to us, therefore, that this apical ossific centre may represent the primary centre of the body of a pro-atlas or last occipital vertebra, and that it is not, as usually supposed, epiphyseal in nature.

Significance of Serial Variations of the Occipito-cervical Region of the Vertebral Column.

The specimens which we have described are of considerable interest with regard to the light which they may throw upon the nature of serial variations of the vertebral column in general. Attempts have been made in the past to explain these variations upon a phylogenetic basis. For instance, it has been considered by certain authors that the occurrence of pronounced variations in individuals indicates the line along which progressive or regressive changes of the vertebral column are gradually taking place in the evolution of the race. Others have regarded these variations as having no general significance, and believe that they are due to some accidental or local cause, such as intrauterine pressure, or disease. Certain cases obviously do fall into this category, and we shall allude to them later.

The bearing that the cases which we have described has upon the main theories which have been advanced, we shall discuss under the following headings.

Tendency towards Lengthening of the Vertebral Column.

The appearance of an additional vertebra in front of the atlas was formerly regarded as an addition to the total number of elements in the vertebral column, and, as we have previously mentioned, was for this reason

called a pro-atlas. Farther, the occasional occurrence of such a vertebra in individuals was regarded as indicating a general tendency towards lengthening of the vertebral column. From what we have stated before, however, this tendency, if present, should not be regarded as a lengthening due to the addition of a new vertebral element, but rather as taking place at the expense of the cranium; or, in other words, by liberation of an occipital vertebra. Now, as the occipital bone of the higher vertebrates has been formed (*vide ante*) by the inclusion in the cranium of vertebræ which were originally separate in the lower vertebrates, the liberation of an occipital vertebra would be regarded by most zoologists as a reversionary or regressive variation.

Tendency towards Shortening of the Vertebral Column.

Fusion of the first cervical vertebra with the occipital bone, on the other hand, has been regarded as indicating a general tendency towards shortening of the vertebral column. If both these theories are correct, we have an indication of variation in two opposite directions, viz., shortening and lengthening of the vertebral column.

Variation about a Mean, with Compensatory Changes in Other Regions.

To harmonise this discrepancy, Dwight, Elliot-Smith, and others have advanced the theory that these variations do not indicate any progressive or regressive change in the direction of shortening or lengthening of the column, but are the expression of variations in these two directions occurring about a mean, and that they are frequently accompanied by compensatory changes in other regions. In other words, the occasional pronounced variations which are described as abnormal are merely exaggerations of slight individual variations which are normally present. The tendency to variation in one region is frequently accompanied by variations in other regions of the body. This appears in some cases to be compensatory, but not in all, as the variations may be of quite a different character, and not serial in type; *e.g.*, in specimen 4 (fig. 4), manifestation of an occipital vertebra is associated with fusion of the atlas, with cervical ribs, and a persistent foramen of Huschke which was present in each tympanic plate. The presence of cervical ribs in this specimen can hardly be regarded as indicating a lengthening of the vertebral column, as, although the thoracic region has been lengthened by one segment, this is at the expense of the cervical region, which is therefore shortened. Possibly the partial liberation of an occipital vertebra in this skeleton might be regarded as a compensatory lengthening

of the cervical region. The fusion of the atlas, however, would appear to negative this view, for the cervical region is diminished in length in both directions, by the assimilation of the atlas with the occipital bone at one end, and the development of cervical ribs at the other.

Arrest of Development.

Arrest of development has been thought to account for some cases of manifestation of an occipital vertebra. The last occipital vertebra is said to be more distinctly marked off from the preceding vertebral elements in the young embryo than it is in older embryos and in the adult, and it is believed that the normal fusion of the last occipital vertebra with the rest of the bone has been prevented. Those cases, however, in which a distinct anterior arch, with a facet for the dens epistropheus upon it (fig. 5), and in which other parts of an occipital vertebra are clearly visible, appear to us to be an advance rather than an arrest of development. Manifestation of occipital vertebræ is, moreover, sometimes associated with the development of additional tendons of insertion for the M. longissimus cervicis, and the M. splenius cervicis. These additional slips are attached to a paracondylar process of the occipital bone (A. W. Verhoef, 21), and their formation can in no sense be regarded as an arrest of development.

In cases of fusion of the atlas with the occipital bone, it is certainly true that the separation of the atlas from the occipital bone by the formation of arthrodial joints is secondary; and that the cartilages of the atlas and occipital bone are primarily united by a continuous tissue, characterised by its staining properties and the large number of closely set nuclei. In cases of fusion of the atlas, this tissue does not break down to form a diarthrodial joint, and in this sense there is an arrest of the normal development of the arthrodial joints between the atlas and condyles of the occipital bone. Arrest of the normal development of these joints does not, however, account for the marked variations in the shape and degree of development of the atlas which are frequently met with in cases of its fusion with the occipital bone, or in which there are other congenital variations in the same subject of a different nature, such as the development of cervical ribs.

Intrauterine Pressure.

It is possible that this may account for some cases. For instance, in specimen 3 (fig. 3)—fusion of the atlas with the occipital bone—on looking at the intracranial aspect of the bone, the region around the foramen magnum appears to be pressed up into the posterior cranial fossa.

Pressure would, however, hardly account for the fusion of the atlas

with the occipital in specimen 4, in which manifestation of an occipital vertebra and cervical ribs were also present in the same subject; for if we regard the fusion of the atlas, the manifestation of the occipital vertebra, and the development of cervical ribs as being associated variations produced by the same cause, we would have to regard the liberation of the occipital vertebra, and the development of cervical ribs, as due to intrauterine pressure, if this was the real cause of fusion of the atlas with the occipital.

Pathological Cases.

A few cases of fusion of the atlas with the occipital bone are undoubtedly due to disease occurring either in utero or after birth. They can usually be distinguished by signs of inflammation, which affect not only the bones immediately concerned but also neighbouring parts. These cases come into another category, and are outside the scope of this paper. We may, however, mention that fusion of the atlas with the occipital bone may, as pointed out by Dwight, favour dislocation of the atlas from the epistropheus, and that if in such a case the individual had survived the injury it might be thought that the fusion of the atlas with the occipital bone was secondary to inflammation set up by the dislocation.

From among the different and often conflicting theories mentioned above to account for congenital variations in the occipito-atlantal region, it is difficult to decide on any one as being the cause in particular cases.

These theories may be summarised as follows:—

(1) Tendency to shortening of the vertebral column.
(2) Tendency to lengthening of the vertebral column.
(3) Variation about a mean, with compensatory changes in other regions.
(4) Arrest of development.
(5) Intrauterine pressure.
(6) Prenatal disease.

Speaking generally, variation about a mean, with compensatory changes in other regions of the body, may be regarded as an established biological principle, which governs or acts on this region as well as on growth and development in general. We would be inclined, therefore, to regard the majority of these variations in the occipito-atlantal region as largely attributable to this cause; and, further, that their occurrence does not point to any special tendency in the direction of either evolution or regression.

In conclusion, we wish to express our thanks to Professor Waterston for kind assistance, and for the use of his valuable serial sections of human embryos; also to Professor Arthur Keith for permission to draw the

specimen fig. 5, showing the hypochordal arch of a last occipital vertebra, in the Museum of the Royal College of Surgeons, England; and, finally, to Mr Walpole Champneys for the skilful manner in which he has executed the drawings.

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THE CRANIAL ATTACHMENT OF THE INTERNAL LATERAL LIGAMENT OF THE LOWER JAW: WITH AN INVESTIGATION INTO THE FIBROGENESIS OF THIS STRUCTURE.

By JOHN CAMERON, M.D., D.Sc., *Lecturer on Anatomy, Middlesex Hospital Medical School.*

I.—THE CRANIAL ATTACHMENT OF THE INTERNAL LATERAL LIGAMENT.

THE internal lateral ligament of the lower jaw has been a mystery to the writer for many years. It is generally regarded as the remains of part of the perichondrium of Meckel's cartilage, but if one considers for a moment how very tiny the latter structure is, one is forced to the conclusion that its connective tissue sheath would give rise merely to the minutest of bands. This has been a difficulty to the writer for a considerable period of time, so that one has felt that there must be other sources for what is frequently a very well-defined and convincing ligamentous structure.

The main purpose of this paper is, first of all, to attempt to clear up a widespread misconception which exists regarding the cranial attachment of this ligament, and in that way obtain a clue to its identity. Thus, in all the text-books which the writer has had access to, the upper end of the ligament is invariably stated to be affixed to the spine of the sphenoid. A close inspection of the course of the ligament, however, will clearly show that, as a matter of fact, it enters the inner extremity of the Glaserian fissure, and, whilst doing so, is merely attached to the spine of the sphenoid *by its inner edge.* The writer would therefore like to suggest that this attachment to the sphenoidal spine simply exists because the latter structure happens to be situated exactly at the inner end of the Glaserian fissure, and is thus purely adventitious, the true morphological attachment being in reality to the lips of the fissure, and also within the tympanic cavity itself, as will be shown presently (fig. 1).

If, now, the attachment of the ligament to the fissure be closely investigated, it will be found that a considerable proportion of the fibres passes right through into the tympanum, and becomes directly continuous with the fibrous layer of the membrana tympani. An interesting and significant fact is that the processus gracilis of the malleus is imbedded in the midst of this fibrous tissue. This intratympanic portion of the internal lateral ligament will be found to be the structure described in text-books as

the anterior ligament of the malleus (*Quain's Anatomy*, 10th edition, vol. iii. part iii. p. 92). This band was for long regarded as containing a bundle of muscle fibres, to which the term laxator tympani was given. In more recent years the existence of these muscle fibres has been questioned. The writer has personally been unable to detect any indications of the presence of this muscle bundle in sections of embryos. Recently Chaine [1] revived this idea in reference to the spheno-mandibular ligament,

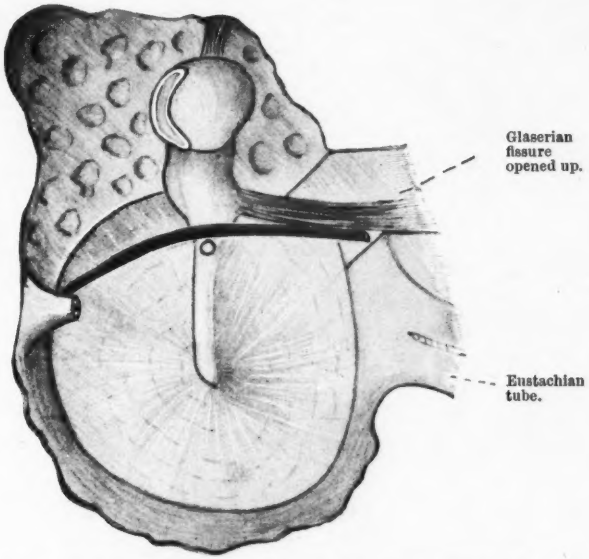

FIG. 1.—A drawing of the inner aspect of the left membrana tympani, showing the continuity of the internal lateral ligament of the jaw, with the anterior ligament of the malleus. Magnified five times.

by describing it as transformed muscle. This point will be referred to again presently.

The chorda-tympani nerve bears a most intimate relationship to the intratympanic portion of the internal lateral ligament, for it is in immediate contact throughout, or practically imbedded in its substance (fig. 1). The association of the nerve to the ligament in the Glaserian fissure is just as intimate, the two in their passage through still maintaining the above close relationship to one another. Therefore the so-called canal of Huguier is not a minute rounded channel for the passage of the nerve,

[1] *Comptes rendus, Biologie*, 1903.

but is in reality represented usually by a rather ragged chink, designed for the passage of both the nerve and the ligament.

II.—The Fibrogenesis of the Spheno-Mandibular Ligament.

As this preliminary investigation of the cranial attachment of the ligament proved so interesting, the writer decided to study its embryology. It forms quite a prominent band in the seventh month fœtus, and passes in the most definite manner upwards into the tympanum through the gap

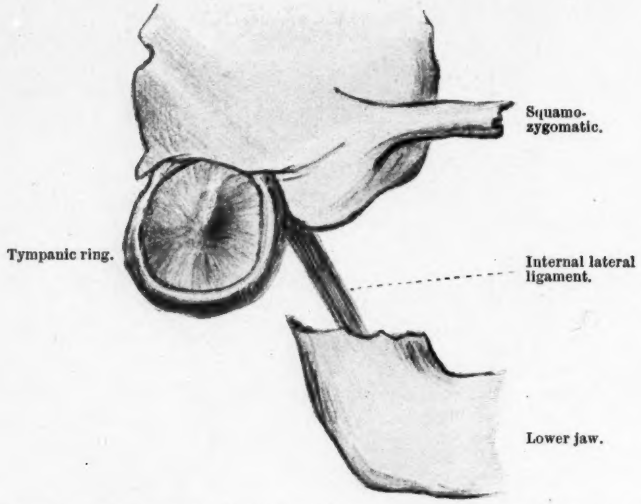

Fig. 2 shows the passage upwards of the internal lateral ligament into the tympanum between the tympanic ring and the squamo-zygomatic element of the temporal bone. It appears to be independent of the sphenoid bone altogether. Magnified about two times. Seventh month fœtus.

between the tympanic ring and the squamo-zygomatic element of the temporal bone (fig. 2). This gap of course becomes the Glaserian fissure after the tympanic ring is transformed into the tympanic plate. In the fœtal tympanum the fibres blend with the fibrous layer of the membrana tympani. A study of the ligament in the fœtus thus absolutely confirmed the impression of its cranial attachment in the adult. It certainly passes between the two elements of the temporal bone in the most decided manner, and very definitely separates them ; and appears, moreover, to be independent of the sphenoid bone at this stage.

On investigating the possible mode of origin of the ligament, the writer was much struck with the presence of a dense mass of mesenchyme surrounding Meckel's cartilage at the point where it is continuous with the malleus in a 32 mm. human embryo.[1] Fig. 3 is drawn from a section on slide 60 of the series, which shows Meckel's cartilage (*m.c.*) apparently

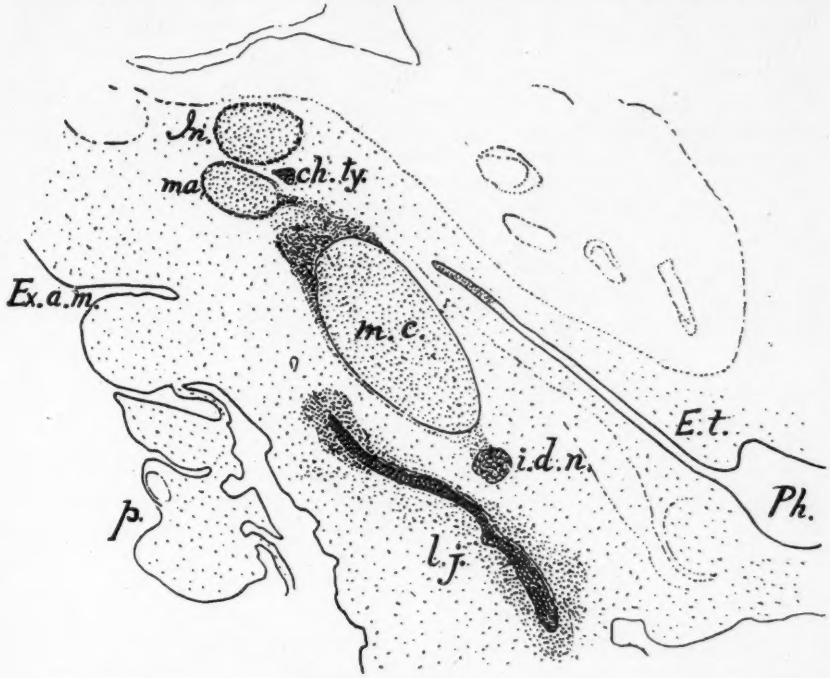

FIG. 3 (from a 32 mm. human embryo) shows a dense mass of mesenchyme lying between the malleus (*ma.*) and Meckel's cartilage (*m.c.*), thus occupying the position of the future "spheno-mandibular" ligament (slide 60). The malleus and Meckel's cartilage were in direct cartilaginous continuity in slide 59. (From a specimen kindly lent by Dr R. J. Gladstone.)

In., incus; *ch.ty.*, chorda tympani; *Ex.a.m.*, ext. aud. meatus; *p.*, pinna; *E.t.*, Eustachian tube; *i.d.n.*, inferior dental nerve; *Ph.*, pharynx; *l.j.*, ossifying lower jaw.

separate from the malleus (*ma.*), the interval being filled up with a compact mass of mesenchyme. The malleus and Meckel's cartilage were, however, shown to be directly continuous in the sections on slide 59. These two structures, in fact, appear to be in direct continuity with one another, up

[1] The writer wishes to express his cordial thanks to Dr R. J. Gladstone for the free use of the serial sections of this embryo.

to the 100 mm. stage at least, for Professor E. Fawcett informs me that this is so in the 100 mm. embryo of his series. Low's 95 mm. embryo[1] shows this also, whilst the reconstructed model of the skull of an 80 mm. embryo figured in Hertwig's *Entwickelungslehre* (fig. 368) demonstrates this fact very clearly too. Also should be mentioned Kölliker's well-known figure showing Meckel's cartilage continuous with the malleus in an eighteenth week human fœtus (which would certainly represent a length of over 100 mm.). At any rate there can be no doubt that between the fifth and seventh months "absorption" of Meckel's cartilage occurs; for by the end of the latter month it has practically entirely disappeared. How has this occurred? So far as I can ascertain, this portion of the cartilage

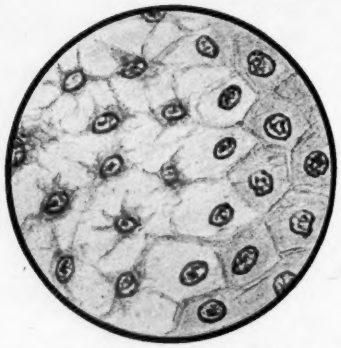

FIG. 4 shows the retrogression of Meckel's cartilage (on the right) into mesenchyme syncytium ×400. Sixth month fœtus.

reverts to its primitive mesenchymatous condition, and this mesenchyme in its turn becomes retransformed into the connective tissue of the internal lateral ligament. This reversion of cartilage back to its early embryonic state is a well-recognised fact, and has been recently emphasised in the case of the developing ribs by Geddes.[2]

There can therefore be no doubt of the fact that the cartilage of Meckel becomes "absorbed," but it is difficult to furnish absolutely authentic proof of the actual process at any given stage. This is not surprising, seeing that the absorption must be spread over a considerable period of time. There are, however, several very suggestive facts which prove that this is actually taking place. First of all, the perichondrium outline becomes indistinct and appears to merge with the surrounding mesenchyme. In

[1] *Journ. of Anat.*, vol. xliv.
[2] *Journ. of Anat. and Phys.*, vol. xlvii. p. 18.

the second place, it will be found that the cell-capsules on the surface of the cartilage become opened into, thus exposing the nuclei with their investing endoplasm, while the capsule-walls, which of course represent the ectoplasm of the cartilage, become directly continuous with the mesenchyme (see fig. 4). I do not think there can be any reasonable doubt, therefore, that this tissue is gradually reverting to its primitive condition of a mesoblastic syncytium, which will later have the power to develop into ordinary connective tissue, and thus give rise to the fibres of the spheno-mandibular ligament.

Another excellent example of retrogression of cartilage to its primitive mesenchymatous condition is afforded by the epihyal element of the second branchial arch which gives rise to the stylo-hyoid ligament. The latter structure thus does not represent merely the perichondrium of the epihyal, as is generally described.

I can find no trace of muscle fibres in the situation of the spheno-mandibular ligament in sections of embryos, and am therefore inclined to question Chaine's (*op. cit.*) conclusion that it is transformed muscle tissue.

SOME FACTORS INFLUENCING THE POSITION OF THE SMALL INTESTINE.

By P. T. Crymble, *Lecturer on Applied Anatomy, Queen's University, Belfast.*

(Read before the Anatomical Society of Great Britain and Ireland at the Middlesex Hospital, 6th March 1914.)

A number of investigators (Henke,[1] Sernoff,[2] Weinberg,[3] Mall[4]) have recorded observations on the position of the jejuno-ileum. They have drawn their conclusions from normal abdomens, and do not discuss the factors which may influence the position of the small intestine or may account for the various abnormal arrangements of jejuno-ileum which one frequently observes. In this paper conclusions have been drawn from all the material examined, whether normal or abnormal, and an attempt has been made to give reasons for the different arrangements.

Mall is the most frequently quoted observer, and his figures are reproduced in many of the text-books. He examined fifty adults, and forty-one of these were free from peritoneal adhesions and abdominal disease. In thirty-five of these forty-one bodies the jejuno-ileum entered into each of the three main divisions of the lower abdomen, *i.e.* the right and left iliolumbar regions and the pelvic cavity.

Addison[5] noted the arrangement of coils, and found the upper third of the jejuno-ileum arranged in horizontal loops in 60 per cent. and the lower third of the jejuno-ileum arranged in vertical loops in 50 per cent. The reason of this arrangement is not discussed.

Method and Material used in this Investigation.

Fifty-six adult human bodies, hardened by injection of formalin, have been examined.

Six of these were frozen for eight days and cut into sections by a hand saw.

[1] Henke, *Archiv für Anatomie*, 1891.
[2] Sernoff, *Internat. Monatsch. für Anat. und Phys.*, 1894.
[3] Weinberg, *Internat. Monatsch. für Anat. und Phys.*, 1896.
[4] Mall, *Reichert's Archiv*, 1897.
[5] Addison, *Journ. of Anat. and Phys.*, vol. xxxv.

In the cases of a girl aged fourteen years, a girl aged twenty years, and a man aged fifty years the sections were horizontal and each slab was made one inch thick.

In two bodies the sections were made by coronal saw cuts, and in the sixth body sagittal sections were made.

The remaining fifty bodies were dissecting-room subjects, very well hardened by formalin injection and immersion in formalin tanks for six to twelve months before being subjected to dissection. In these bodies the abdomen was opened by a crucial incision, and the lower ribs on the left side removed by saw cuts. A sketch of the small intestine was then made on a prepared diagram showing the bony framework and the inner margins of the psoas muscles.

In most cases the course of the small intestine in the pelvic cavity was too complicated to record.

On a second similar diagram the large intestine, liver, stomach, and bladder were sketched.

The Normal Position of the Jejuno-Ileum.

The peritoneal cavity may be subdivided into four main regions:—

1. The subphrenic region, or that part lying superior to the transverse mesocolon.

2. The right ilio-lumbar region—a space, triangular in outline, bounded superiorly by the transverse mesocolon, laterally by the lateral abdominal wall, and medianly by the mesentery of the jejuno-ileum and by the right psoas margin.

3. The left ilio-lumbar region—bounded superiorly by the transverse mesocolon and the phrenico-colic ligament, laterally by the lateral abdominal wall, medianly by the jejuno-ileum mesentery, and inferiorly by the left psoas margin and the sacral promontory. It is more extensive than the right ilio-lumbar region, since it extends superiorly to a greater extent and is broader inferiorly.

4. The pelvic region—separated from the ilio-lumbar regions by the sacral promontory and the inner margins of the two psoas muscles.

Of the fifty-six bodies examined only nineteen were free from bladder or stomach distension, enteroptosis, or peritoneal abnormalities.

In six of the nineteen the jejuno-ileum was confined to the left ilio-lumbar and pelvic regions, and in the remaining thirteen the small intestine was distributed over both ilio-lumbar regions and the pelvic region. The amount of small intestine entering the right ilio-lumbar region was, as a rule, much less than that entering the other two regions.

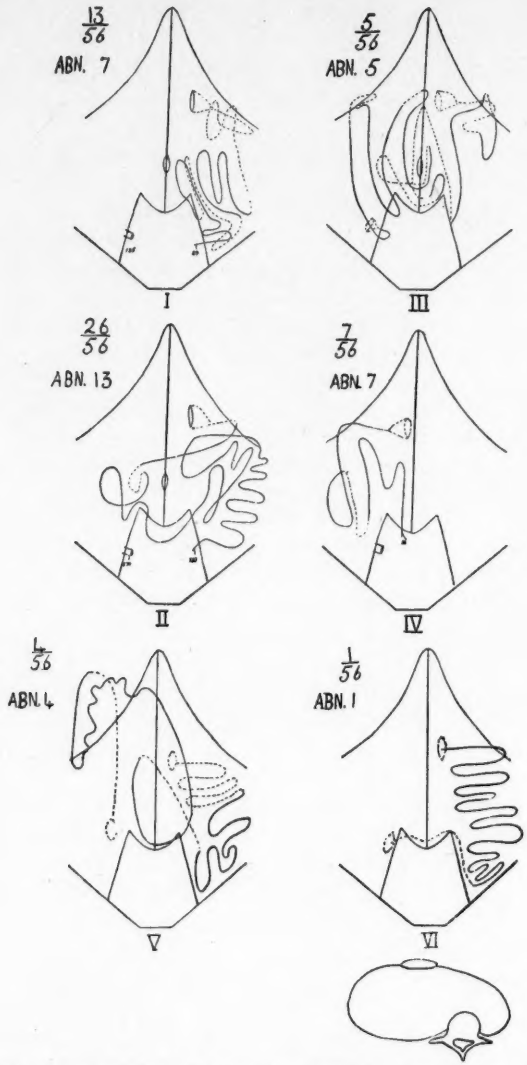

FIG. 1.—Shows the six arrangements of jejuno-ileum found in an examination of fifty-six bodies. Each diagram shows the course of the ilio-lumbar small intestine. The course of the pelvic small intestine is too complicated to figure. The costal margin, mid-line, umbilicus, sacral promontory, inner margin of psoas, the inguinal ligaments, and the pubic crests are shown. The figures at the top left-hand corner of each diagram indicate the number of times the arrangement occurred. ABN. followed by a figure indicates the number of times a disturbing factor was present. *E.g.*, enteroptosis, distended bladder, or abnormal peritoneal fold. It will be noticed that all the cases in groups III, IV, V, and VI were associated with some disturbing factor.

Below group VI is a drawing of a horizontal section which shows the marked increase in the size of the left ilio-lumbar region in a case of lateral curvature, convex to the right.

In twenty-six bodies the small intestine entered both ilio-lumbar regions and the pelvic cavity, and of these twenty-six the following may be recorded :—

Male aged forty-two years :
One loop of jejuno-ileum in the iliac fossa below the cæcum.
L.I.L. (left ilio-lumbar region) . . . . . 1–55 inches.
R.I.L. (right ilio-lumbar region) and P. (pelvis) . 56–79 „
Pelvic mesocolon laden with fat.
Large space above the bladder (probably the bladder had been previously distended with urine).

Male aged sixty years, body 9 :
Distension of the small intestine due to a colic stricture
Cæcum and ascending colon covered by small intestine.

Male aged sixty years, body 2 :
L.I.L. . . . . 1–77 and 96–132 inches.
P. . . . . 78–95 „
R.I.L. . . . . 132–184 „
Pelvic cavity diminished in size by a deposit of extra-peritoneal fat and contained a partially distended and long pelvic colon.

Female aged twenty-eight years :
L.I.L. . . . . 1–26 inches.
P. . . . . 27–46 „
R.I.L. . . . . 47–110 „
Much extra-peritoneal fat in the pelvic cavity. Massive pelvic mesocolon and large appendices epiploicæ.

Male aged thirty-nine years :
Several inches of the small intestine in the median part of the right iliac fossa. Fundus of the cæcum fixed in an inverted position by a parieto-cæcal fold.

Male aged thirty-one years :
Pelvic cavity occupied by a dilated pelvic colon and contained only a few inches of small intestine. Cæcum and colon very contracted. Valvula coli above the intertubercular plane.

Female aged twenty-seven years :
Low attachment of the transverse mesocolon, the splenic flexure being on the iliac crest.

Male aged forty-eight years :
Pelvic cavity occupied chiefly by the distended pelvic colon and a large hard bladder.

Female aged seventy years :
One loop in a lateral paracæcal fossa, the remainder of the small intestine being confined to the left ilio-lumbar and pelvic regions.

Male aged forty-nine years :
L.I.L. . . . . 1–18 inches.
R.I.L. . . . . 31–48 „
P. Remainder of small intestine.
Total length of small intestine 158 inches.
Left ilio-lumbar region chiefly occupied by the transverse colon.

In a male (body 28, 1912–13) :
1–53 inches, with the exception of one loop crossing the right psoas, lay in the left ilio-lumbar region. The remainder lay in the pelvic cavity.

In many of the above cases there is a definite cause for the presence of a considerable quantity of small intestine in the right ilio-lumbar region. In some only a few inches have entered the space.

Abnormal Positions of Jejuno-Ileum.

1. The small intestine is excluded from the pelvis, and is confined to the ilio-lumbar regions. Present in five.

Causes:—

(*a*) Female aged thirty years. Pelvic cavity occupied by a distended rectum and pelvic colon. A large amount of extra-peritoneal fat diminished the size of the pelvic peritoneal cavity.

(*b*) Male aged sixty-eight years and a female aged sixty-eight years. Distension of the bladder.

(*c*) Male aged seventy-five years. Great distension of the rectum.

(*d*) Female aged sixty-nine years. Pelvic cavity occupied by the uterus, a distended rectum, and the pelvic colon.

2. The small intestine is confined to the right ilio-lumbar and pelvic regions, or a few inches only are admitted to the left ilio-lumbar region. Present in seven.

Causes:—

(*a*) The distal third or fourth of the transverse colon is fixed to the posterior abdominal wall by an abnormal peritoneal membrane. Present in three cases, *i.e.* a female aged sixty-one years, a female aged sixty-five years, and a female aged eighty years (see figs. 2 and 3 and 21).

(*b*) Enteroptosis. Present in two cases, *i.e.* a female aged seventy-six years (see figs. 4 and 5) and a female aged thirty-five years.

(*c*) Left ilio-lumbar region occupied by a distended ascending limb of the transverse colon and a distended descending colon. Present in a female aged thirty-nine years.

(*d*) Left ilio-lumbar region occupied by the cæcum, a large part of the transverse colon, and the first eight inches of jejunum. Present in a male aged seventy-two years.

3. The small intestine enters the subphrenic region. Present in four.

Causes:—

(*a*) Distension of the bladder. Present in a man aged forty-three years.

Left ilio-lumbar region . . . . 1–89 inches.
Right ilio-lumbar and subphrenic regions . 90–172 „

Some coils of ileum passed upwards in front of the transverse colon, and lay in contact with the right lobe of the liver.

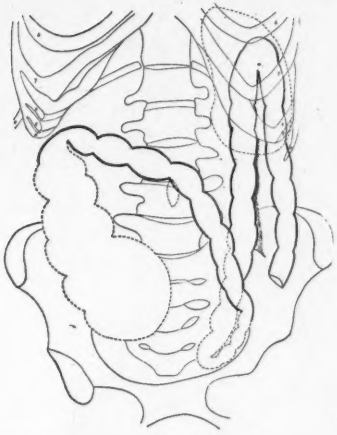

FIG. 2.—Abnormal arrangement of peritoneum. The tranverse colon forms a long V-shaped loop, the apex of which lies in the pelvis. The distal third of the transverse colon is adherent to the posterior abdominal wall. This arrangement of colon prevented the entrance of small intestine into the left ilio-lumbar region, and resulted in the cæcum and ascending colon being covered by small intestine.

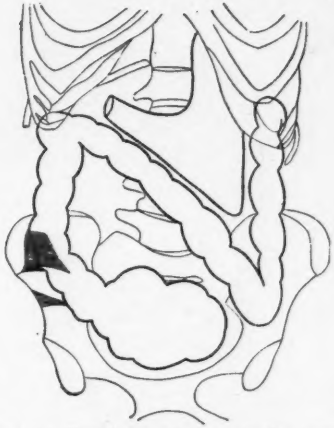

FIG. 4.—Female aged seventy-six years. Marked enteroptosis. The colon was filled by scybalous masses. Right parieto-colic fold, behind which was a loop of small intestine. The main mass of the ilio-lumbar small intestine lay between the ascending and transverse colons. Owing to the left ilio-lumbar region being occupied by a stomach distended and low in position, and by a colon laden with scybala, only two inches of small intestine lay in that region.

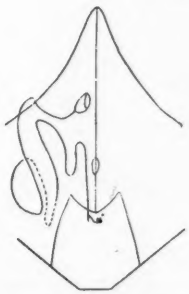

FIG. 3.—Abnormal position of small intestine. Shows the arrangement of the small intestine in the right ilio-lumbar region of the case illustrated in fig. 2. The small intestine occupied the right ilio-lumbar and pelvic regions. The pelvic loops were too complicated to figure. There was no small intestine in the left ilio-lumbar region.

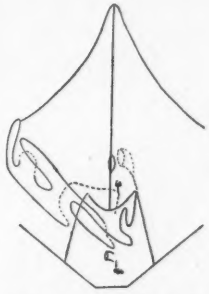

FIG. 5.—Course of the ilio-lumbar small intestine in the female aged seventy-six years, illustrated in fig. 4. Marked enteroptosis, the valvula coli lying at the bottom of the pelvis. Only two inches of small intestine lay in the left ilio-lumbar region.

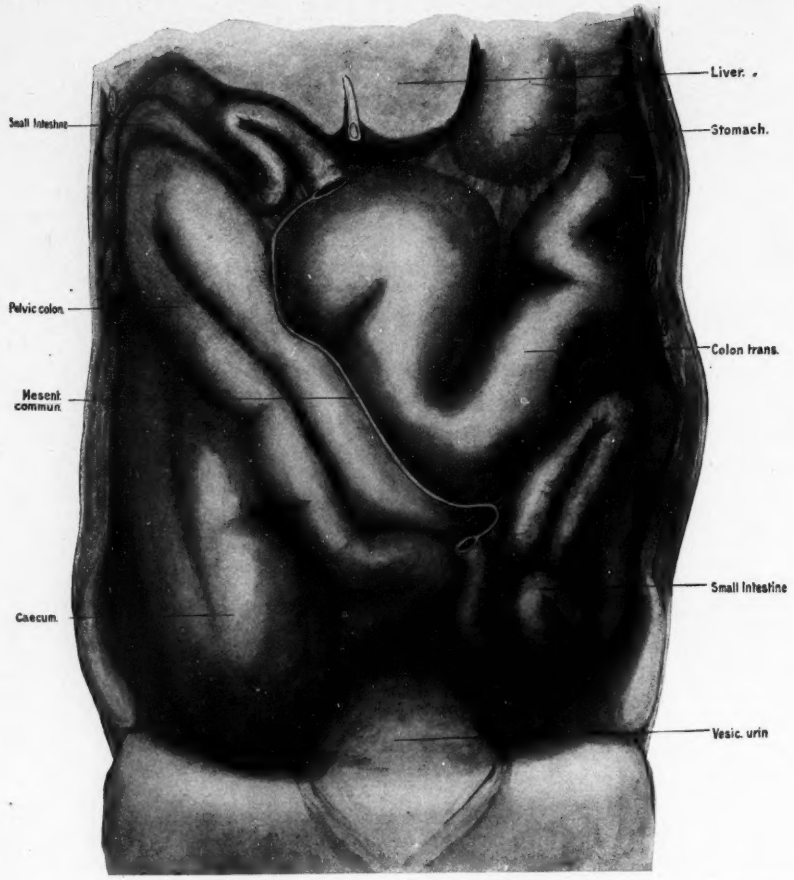

FIG. 6.—Abdominal viscera of a male aged sixty-four years, viewed from the front. The urinary bladder is distended and entirely fills the pelvic cavity. The cæcum and transverse colon are enormously distended with soft fæces. The descending and iliac colon, concealed from view by transverse colon and coils of small intestine, are slightly larger than normal. The pelvic colon forms a ∩-shaped loop, directed upwards and to the right. The apex of this loop and some coils of small intestine are seen lying in front of the liver. They intervened between the liver and the ribs, occupying the right anterior intraperitoneal subphrenic space. This abnormal arrangement of small intestine was due to three factors: (*a*) the distension of the bladder; (*b*) the distension of the cæcum, ascending and transverse colons; (*c*) the fixation of the distal five inches of transverse colon to the posterior abdominal wall (see fig. 7).

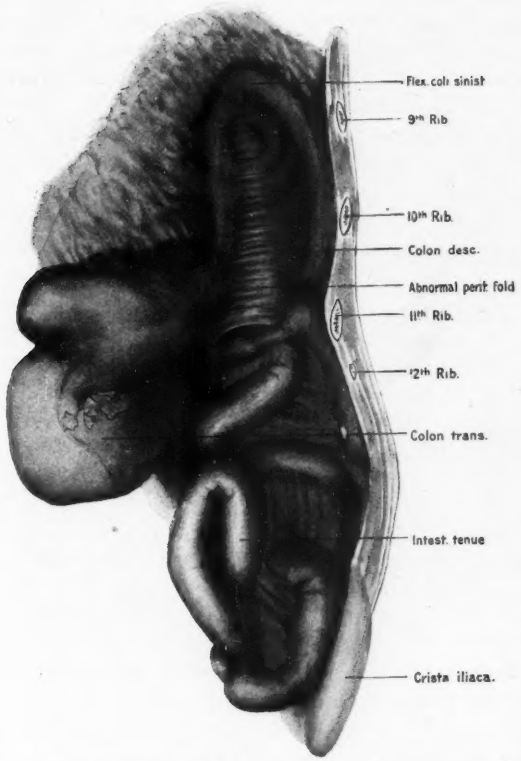

FIG. 7.—Abdominal viscera of a male aged sixty-four years, viewed from the left side. The anterior abdominal wall and portions of the lower four ribs on the left side have been removed. Portions of large and small intestine are exposed. The transverse colon, distended with soft fæces, is attached in the terminal part of its course, for a distance of five inches, to the posterior abdominal wall by a peritoneal fold. This fold is attached, posteriorly, median to the descending colon and has produced a marked kink at the left colic flexure (O.T. splenic flexure). It has also prevented jejunum from entering the upper part of the left ilio-lumbar region.

(*b*) Distended bladder and fixation of the distal five inches of the transverse colon to the left posterior abdominal wall (see figs. 6 and 7). Present in a male aged sixty-four years. Coils of small intestine lay in the right anterior intraperitoneal subphrenic space.

(*c*) Adhesion between the transverse colon and the left lateral abdominal wall. Present in a female aged seventy-four years. The small intestine was arranged thus:—

Left ilio-lumbar region . . .	1–5 and 75–91 inches.
Right ilio-lumbar region and right anterior intraperitoneal subphrenic space . . .	6–75 „
Pelvic region	remainder.

(*d*) Abnormal arrangement of the peritoneum with a free communication between the gastric recess of the lesser sac and the ilio-lumbar region. Present in a female aged sixty-five years, in whom the gastric recess was filled by coils of small intestine. A study of fig. 8 will show that the transverse colon passes below the root of the mesentery and behind the coils of small intestine, and is fixed in this position by adhesion to the posterior abdominal wall. The upper region of the abdomen is completely shut off from the lower region by a peritoneal membrane attaching the proximal fourth of the transverse colon and the great curvature of the stomach to the anterior abdominal wall, and the peritoneal cavity of this lower region passes freely upwards behind the stomach, where it is separated from the bursa omenti minoris by a complete septum bursarum composed of gastrophrenic and gastro-pancreatic folds.

The bursa omenti minoris and the peritoneal cavity in relation to the liver are normal. A gastro-splenic ligament is present, but it has no connexion with the peritoneal diaphragm above described, and it shows a free lower border.

There are two possible explanations of this condition:—

(1) That the colon rotation has not taken place in the usual manner, and adhesion between the transverse colon and the posterior wall of the lesser sac has been prevented by the coils of small intestine. The lower part of the lesser sac has been invaginated into the gastric recess.

(2) The small intestine has burst through the transverse mesocolon, entered the lesser sac, and then burst through the great omentum, thus forming a free communication between the great sac and the gastric recess.

4. The small intestine is confined to the left ilio-lumbar region. Present in one.

This was a case of spinal curvature in a female aged sixty years. The spine was laterally curved, convex to the right, so that the dorso-lumbar region of the spine lay considerably to the right of the mid-line. There was a very marked increase in the size of the left ilio-lumbar region and a corresponding decrease in the size of the right ilio-lumbar region. The

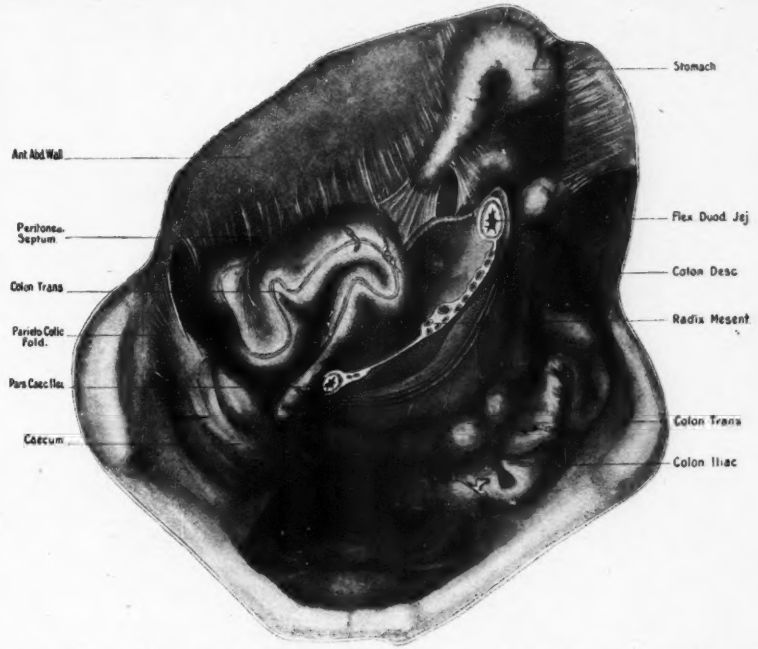

FIG. 8.—Abnormal arrangement of peritoneum and transverse colon. The transverse colon passed below the root of the mesentery and behind the jejuno-ileum. Throughout its whole course it was closely adherent to the posterior abdominal walls or to viscera lying on the posterior abdominal wall. The left ilio-lumbar region communicates freely with a retro-gastric space. The small intestine occupied the retro-gastric space, the left ilio-lumbar region, and the pelvic cavity.

jejuno-ileum was arranged in transverse loops and only passed out of the left ilio-lumbar region to join the colon (see fig. 1 (vi)).

FACTORS INFLUENCING THE POSITION OF THE SMALL INTESTINE.

1. *In the Right Ilio-lumbar Region.*—Normally the cæcum, ascending colon, and the proximal third or half of the transverse colon are dilated and are capable of almost entirely filling the right ilio-lumbar region.

If the first part of the transverse colon descends parallel and median to the ascending colon, the probability of small intestine entering this region will be still less.

In nineteen of the fifty-six bodies the small intestine did not enter this region, and in six of these thirteen there was no abnormality, but the space was fully occupied by the distended cæcum and colon. In five of the remainder there was distinct enteroptosis, *e.g.*:—

Male aged sixty-eight years—liver in the right iliac fossa, horizontal part of the duodenum lies below the bifurcation of the aorta.

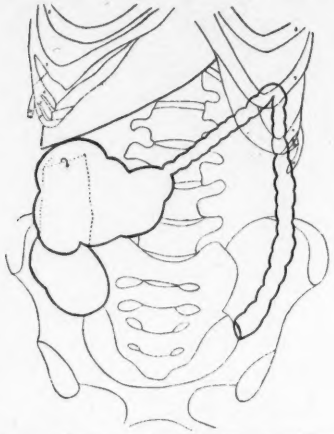

FIG. 9.—Sketch of the colon in a female aged thirty-one years. The first part of the transverse colon is distended and overlies the ascending colon. The remaining part of the transverse colon is much contracted.

FIG. 10.—Course of the right and left ilio-lumbar small intestine in the female aged thirty-one years, illustrated in fig. 9. Ninety-five inches of small intestine lay in the left ilio-lumbar region, the remaining fifty-two inches of small intestine, with the exception of one loop, lay in the pelvis.

The right ilio-lumbar region was occupied by distended colon (see fig. 9) and admitted only a few inches of small intestine.

Female aged eighty years—ptosis of colon and colic flexures.

In the remaining two the colon occupied an abnormal position, a large part being fixed in the right ilio-lumbar region (see figs. 11 and 12).

There are two areas in the right ilio-lumbar region frequently occupied by small intestine, *i.e.* the lower part of the iliac fossa and the space between the cæcum and the transverse colon. Small intestine enters the former where the cæcum is small or occupies a high position (see figs. 13 and 14).

Where the small intestine is unable to enter the pelvic cavity owing to distension of the bladder, rectum, or uterus, an increased amount of it lies in the right ilio-lumbar region; and a similar condition exists if the left ilio-lumbar region is unable to admit small intestine.

Normally the cæcum is in contact with the anterior abdominal wall (see fig. 16), but the jejuno-ileum insinuates itself when it is driven out of the left ilio-lumbar region (see fig. 2).

2. *The Left Ilio-lumbar Region.*—As a rule a large part of the jejunum lies in this region, and when no other viscus encroaches excessively it

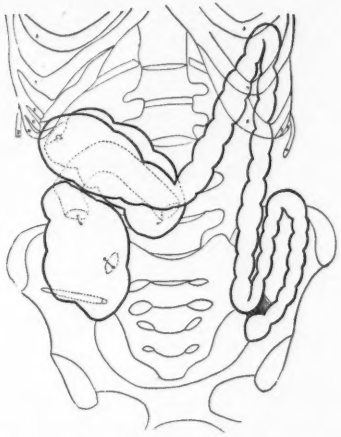

FIG. 11.—Abnormal arrangement of the transverse and pelvic colons. The apex of a loop of transverse colon was fixed to the hepatic flexure, the loop and the proximal few inches of the transverse colon forming a closely united triple-barrelled arrangement. Three well-marked angulations were present (see arrows). The limbs of a loop-shaped pelvic colon were closely united at the base of the loop.

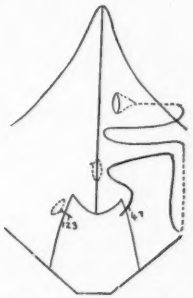

FIG. 12.—Arrangement of the ilio-lumbar small intestine in a male aged fifty-two years, in whom the transverse colon was abnormally arranged and prevented the small intestine entering the right ilio-lumbar region (see fig. 11).

arranges itself in horizontal loops. The transverse colon lies anterior to this jejunum, and the descending colon lies posterior to it. The relation of the iliac colon is variable, being at times covered by small intestine and at times in contact with the anterior abdominal wall.

The various conditions which prevent the entrance of small intestine into this region, *i.e.* abnormal peritoneal fold, enteroptosis, dilated colon, are mentioned previously under Abnormal Positions of Small Intestine. In addition to these, one may mention three pathological conditions, viz., enlarged spleen, enlarged kidney, enlarged left lumbar lymph glands.

The last one was associated with new growths of the left testis, and the small intestine was forced into the right ilio-lumbar region. Distension of the stomach drives the small intestine from this region.

In one case (fig. 1) all the small intestine, with the exception of the pars cæcalis ilei, lay in the left ilio-lumbar region and was arranged in a series of horizontal loops.

3. *The Pelvic Cavity.*—This contains the chief mass of the ileum.

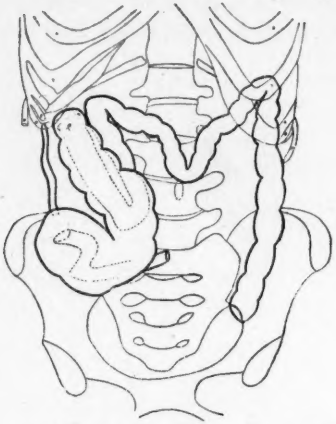

FIG. 13.—Male aged sixty-three years. The fundus of the cæcum is fixed in a high position by a pre-renal appendix. Kinks are present in the pars cæcalis ilei and at the hepatic flexure. The first few inches of the transverse colon descends retro-peritoneally behind the ascending colon.

The high position of the cæcum permits small intestine to enter the lower part of the right iliac fossa (see fig. 14).

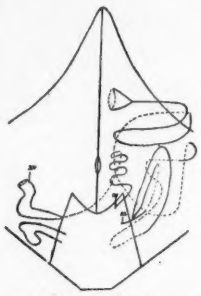

FIG. 14. — Male aged sixty-three years. Course of the right and left ilio-lumbar small intestine. A loop of ileum occupies the lower part of the right iliac fossa. The first eighty-two inches of small intestine is seen lying in the left ilio-lumbar region. Inches 82–178 occupied the pelvis, but are not figured. The portion 178–210 re-entered the left ilio-lumbar region and then passed downwards and to the right towards the valvula coli. Owing to the high position of the cæcum, a loop of ileum was permitted to enter the lower part of the right iliac fossa.

Owing to the greater capacity of the female pelvic cavity there is usually more pelvic small intestine in the female than in the male.

The terminal portion of the ileum passes upwards and forwards from the bottom of the pelvic cavity to the valvula coli, situated in the right iliac fossa. During its course it lies against the right lateral wall of the pelvis, and as it crosses the right psoas margin it can be rolled under the palpating fingers and can be easily recognised, especially during contraction of the psoas muscle.

In a minority of cases it passes obliquely downwards from the left ilio-lumbar region to the right iliac fossa.

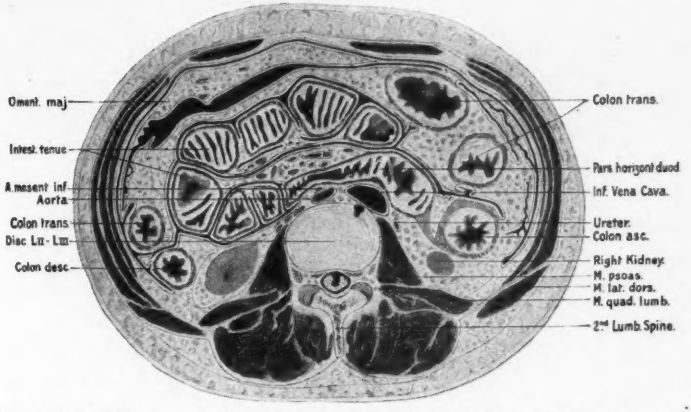

FIG. 15.—Horizontal section of a girl aged fourteen years, through the disc between the second and third lumbar vertebræ. The right ilio-lumbar region is chiefly occupied by transverse colon, ascending colon, and duodenum.

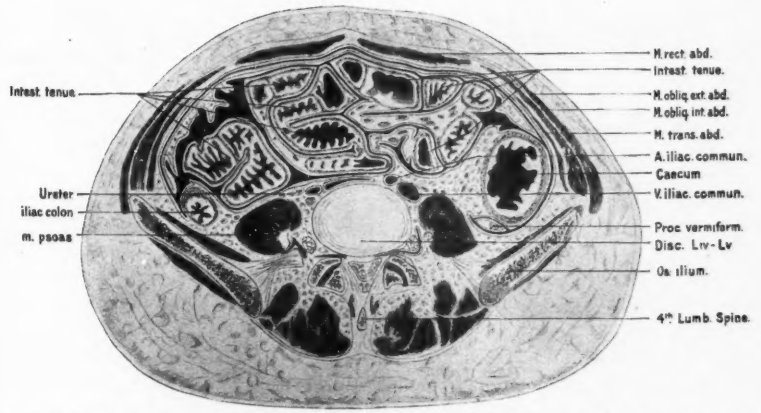

FIG. 16.—Horizontal section of a girl aged fourteen years, through the disc between the fourth and fifth lumbar vertebræ. The cæcum, as usual, fills the right iliac fossa, and is lying in contact with the anterior abdominal wall. The iliac colon is in its normal contracted condition and is covered by small intestine.

The fixation of the pelvic colon to the left side of the pelvic cavity influences the ileum to occupy the right side of this region.

The following conditions diminish the capacity of the pelvic cavum peritonæi and more or less completely prevent the ileum entering:—

(*a*) Excessive amount of extra-peritoneal fat.
(*b*) Distension of the bladder.
(*c*) Distension of the rectum.
(*d*) Enlargement of the uterus.
(*e*) Distended pelvic colon occupying this region.

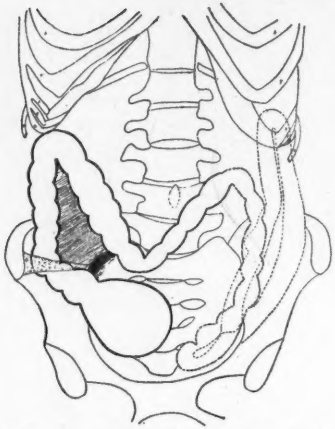

FIG. 17.—Female aged sixty-seven years, showing enteroptosis and a median paracolic fossa formed by a peritoneal membrane connecting the ascending and transverse colons. This fossa contained a twenty-seven-inch loop of ileum.

The portion of transverse colon indicated by dotted lines was overlain by jejunum.

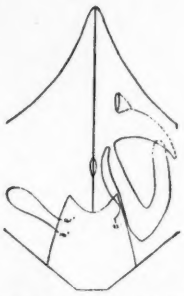

FIG. 18.—Sketch of the ilio-lumbar small intestine in a female aged sixty-seven years (see fig. 17).

4. *In the Subphrenic Region.*—Small intestine came in contact with the diaphragm in four of the fifty-six cases. In three of these a peritoneal abnormality accounted for the arrangement, and in the fourth case there was a distended bladder.

As a rule the small intestine is forced upwards in front of the transverse colon into contact with the right lobe of the liver and the costal margin, but in the very rare case illustrated in fig. 8 the small intestine passed upwards into the gastric recess of the lesser sac.

ARRANGEMENT OF JEJUNUM IN LEFT ILIO-LUMBAR REGION.

The arrangement of the jejunum in the left ilio-lumbar region was recorded in forty-five bodies.

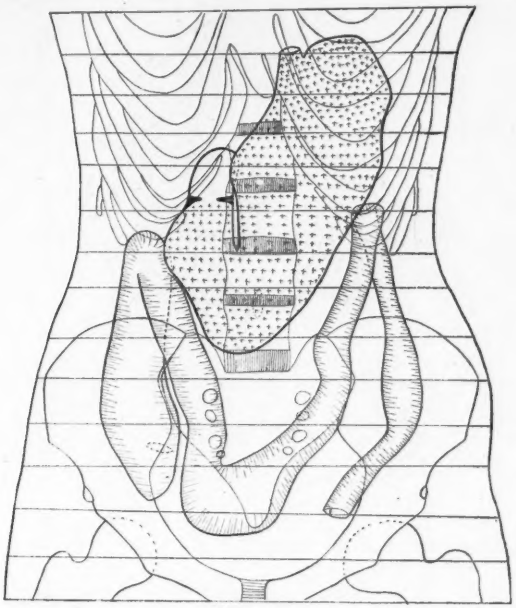

FIG. 19.—Reconstruction of the stomach and colon from a series of horizontal sections, through the abdomen of a girl aged twenty years. There is marked enteroptosis.

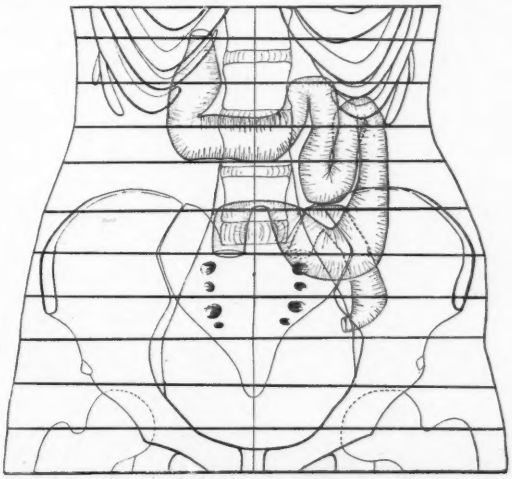

FIG. 20.—Reconstruction of the duodenum and left ilio-lumbar small intestine from a series of horizontal sections, through a girl aged twenty years. There is marked enteroptosis, and, with the exception of the few loops lying in the left ilio-lumbar region, all the jejuno-ileum lay in the pelvic cavity.

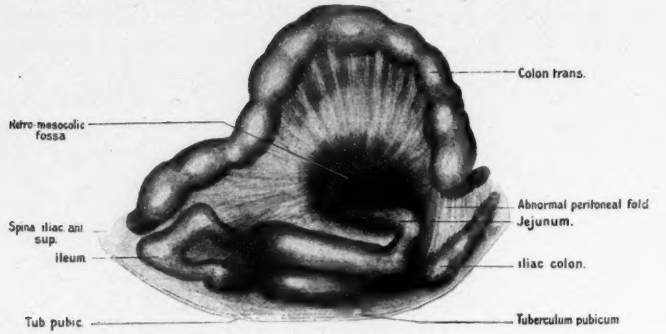

FIG. 21.—Female aged eighty years. All the jejuno-ileum lay in the pelvic cavity, except a loop lying anterior to the cæcum and the first five inches of jejunum, which lay in a retro-mesocolic fossa in the left ilio-lumbar region. This fossa was bounded on the right and anteriorly by the transverse meso-colon. On the left it was bounded by an abnormal peritoneal fold which fixed the terminal fourth of the transverse colon to the posterior abdominal wall, median to the iliac and descending colons. The result of this arrangement of peritoneum is the almost complete absence of jejuno-ileum from the left ilio-lumbar region and the presence of jejuno-ileum in front of the cæcum.

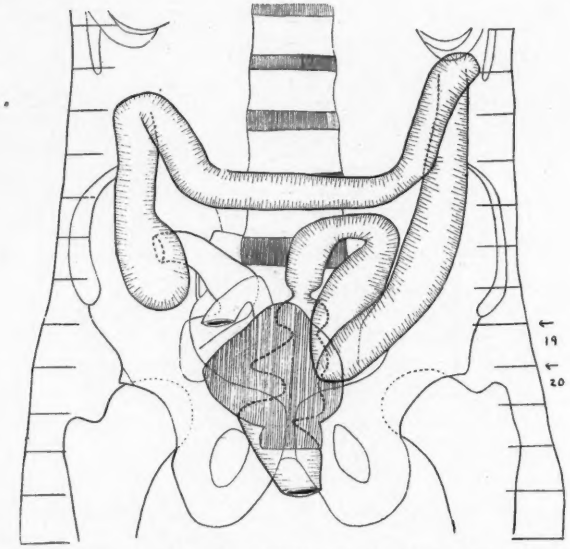

FIG. 22.—Reconstruction of the urinary bladder, the terminal portion of the ileum, the cæcum, the colon, and the rectum, from a series of horizontal sections through a man aged fifty years. Rectal constrictions are well marked. The upper surface of slab 19 is seen in fig. 24.

In eleven the jejunum was arranged in horizontal loops, and all these abdomens were normal.

In twenty the jejunum was arranged in vertical loops; but of these twenty, fourteen showed some encroachment on the left ilio-lumbar region by either a distended stomach (ten cases) or an abnormal colon (four cases).

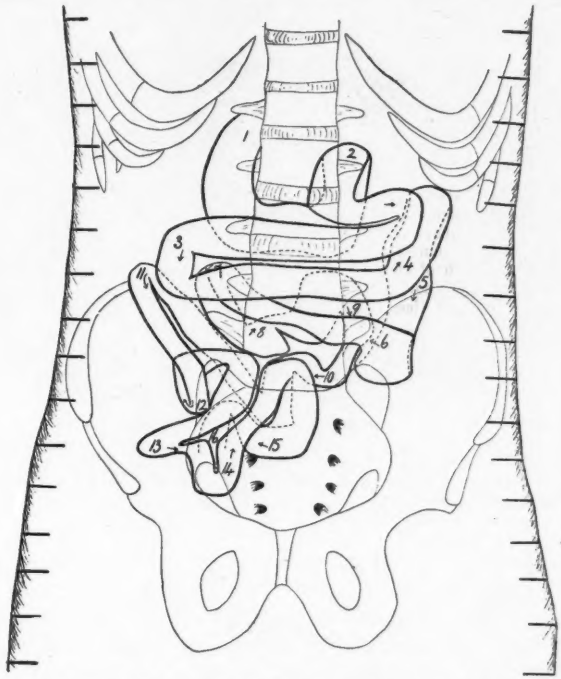

FIG. 23.—Reconstruction of the small intestine of a man aged fifty years. It is unusual to find the small intestine so evenly distributed between the right and left ilio-lumbar regions. Reference to fig. 22, where a reconstruction of the bladder and colon is illustrated, will demonstrate the factors controlling this arrangement. The descending and iliac colons are abnormally distended. The bladder occupies a large part of the pelvic cavity and is in a distended condition.

In fourteen the arrangement could not be classified owing to irregularity of the loops, and ten of these fourteen showed abnormalities, *i.e.* six—no small intestine in the pelvic cavity; two—distended stomach; two—abnormal colon.

It would appear, therefore, that the upper part of the small intestine is normally arranged in horizontal loops, but that this arrangement gives

place to vertical loops in the presence of any factor diminishing the left ilio-lumbar small intestine space.

In support of this conclusion it may be noted that in the case of enlargement of the left ilio-lumbar region, due to lateral curvature, the entire mass of jejuno-ileum was accommodated in this space and arranged itself in horizontal loops.

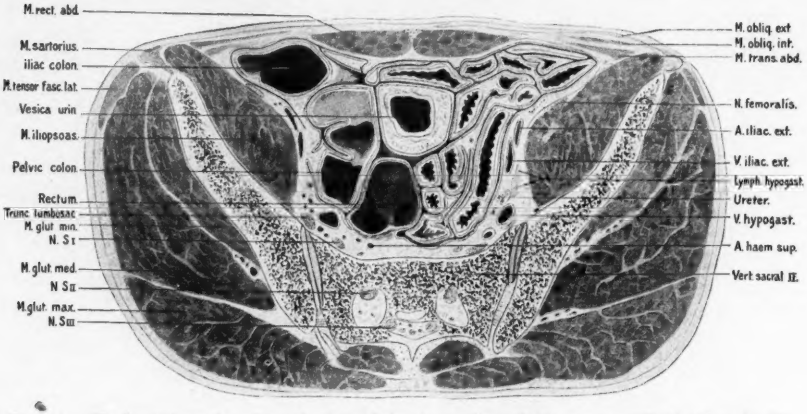

FIG. 24.—Horizontal section through the pelvis of a man aged fifty years. The fundus of a distended bladder, separated from the anterior abdominal wall by a coil of ileum, is seen in the centre of the section. The left half of the pelvic cavity is occupied by pelvic colon. Numerous coils of ileum fill up the right half of the pelvic cavity. The level of this section in the reconstruction (fig. 22) is indicated by the arrow above the figure 19.

APPLIED ANATOMY.

The interpretation of the various percussion notes obtained over the abdomen is facilitated by a clear conception of the probable position of the small intestine, *e.g.*, the absence of the usual cæcal note may lead the observer to the discovery of an abnormal peritoneal arrangement in the left ilio-lumbar region whereby small intestine is forced between the cæcum and the anterior abdominal wall, or the loss of the cæcal note may be due to distension of the small intestine.

It must be noted that the position and relations of abdominal viscera may be altered by opening the cavum peritonæi in the living person, since the intra-abdominal positive pressure will drive the mobile small intestine towards the opening.

The X-ray examination of the bismuth meal shows the jejuno-ileum bismuth as scattered dark areas, chiefly in the pelvis. No doubt in the erect position the main mass of the small intestine lies in the pelvis.

Summary.

1. Fifty-six adult bodies were examined.

2. Six bodies were frozen and cut into sections.

3. In twenty-six bodies the small intestine entered both ilio-lumbar regions and the pelvic cavity.

4. In thirteen bodies the small intestine was confined to the left ilio-lumbar and pelvic regions.

5. In five bodies the small intestine was confined to the ilio-lumbar regions.

6. In seven bodies the small intestine was confined to the right ilio-lumbar and pelvic regions.

7. In four the small intestine entered the subphrenic region.

8. In one the small intestine was confined to the left ilio-lumbar region.

9. In the normal abdomen the jejuno-ileum lies in the ilio-lumbar regions and the pelvic cavity, or is confined to the left ilio-lumbar region and the pelvic cavity.

10. *Physiological Alterations.*—The pelvic small intestine is forced into the ilio-lumbar regions by distension of the bladder, rectum, or uterus. Distension of the cæcum and ascending colon forces small intestine out of the right ilio-lumbar region, and distension of the stomach forces small intestine out of the left ilio-lumbar region. Small intestine lies anterior to the upper end of a distended bladder (see fig. 24).

11. *Anatomical Variations.*—Fixation of the distal third of the transverse colon to the posterior abdominal wall confines the small intestine to the right ilio-lumbar and pelvic regions, and is associated with the presence of small intestine in front of the cæcum.

12. Enteroptosis is associated with the absence of small intestine from the right ilio-lumbar region. In marked enteroptosis the small intestine is almost entirely confined to the pelvic cavity (see figs. 19 and 20).

13. When there is a sufficient amount of room the jejunum tends to arrange itself in horizontally placed coils in the left ilio-lumbar region.

14. The presence of small intestine in the subphrenic region is abnormal, and is associated with some peritoneal variations or excessive distension of some viscus.

A PLEURAL FOLD CONTAINING THE VENA AZYGOS.

By JOHN R. D. HOLTBY, M.B., B.S., *Chief Demonstrator of Anatomy, Trinity College, Dublin.*

CASES in which an extra lobe or process of the right lung is found accommodated within a pleural cul-de-sac and associated with an irregularity in the course of the vena azygos are sufficiently rare in the human subject to merit record. Professor Waterston informs me that the condition

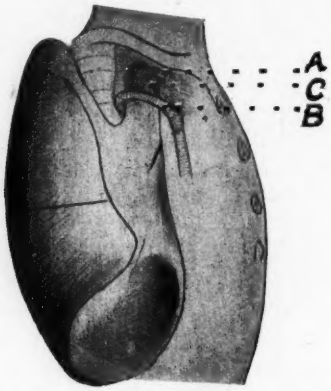

FIG. 1.—The specimen viewed from the front; the lung is drawn backwards and outwards.

A, pleural fold; C, accessory process; B, vena azygos.

is constant in the porpoise, and if the explanation here advanced be correct, it is remarkable that it is not more commonly met with in man. Specimens have been described and theories advanced as to its causation by Chiene, Cleland, Collins, and Geddes in this country, and abroad by numerous observers, more especially Fischer, Bluntschli, and Du Séjour.

The specimen here described was obtained from an aged female subject submitted for dissection in November 1913.

The thoracic cavity showed no other anomalies and the pleura was free from adhesions. On drawing back the right lung, a distinct pleural fold was seen passing down from the thoracic apex (fig. 1). Lying between

this fold and the mediastinal pleura was a tongue-shaped process of pulmonary tissue which had its root on the inner surface of the highest lung lobe just behind the hilum. The cleft between this process and the main lung mass was deepest at the posterior border, where it was only separated from the great oblique fissure by a thin bridge of pulmonary substance. In conformity with this, the lower border of the pleural fold showed its greatest curvature posteriorly. The lower margin of the fold lay opposite the disc between the 5th and 6th dorsal vertebræ, and contained between its layers the vena azygos.

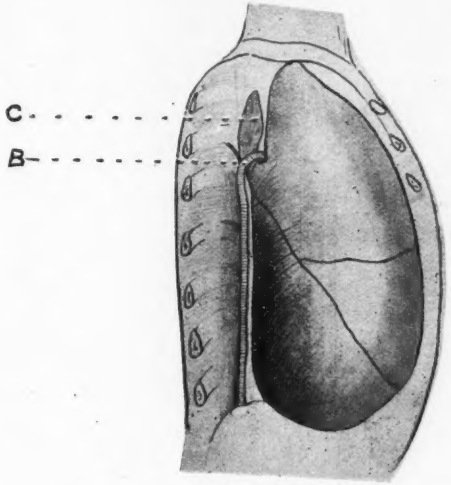

FIG. 2.—The specimen viewed from behind; the lung is drawn forwards.

C, accessory process of lung; B, vena azygos.

The accessory pleural sac lying to the medial side of this fold, or mesoazygos, extended upwards to the lower border of the 7th cervical vertebra. Anteriorly it was bounded by the junction of the fold with the mediastinal pleura along the line of the vena cava superior; posteriorly by its junction with the vertebral pleura. The superior intercostal vein ran forwards and downwards from the posterior thoracic wall between the layers of the fold to reach the vena azygos in its lower border.

The pleural apex seemed, therefore, to have been divided by the vena azygos, which, cutting it rather to the medial side of its central point, pulled down from it a double fold and so separated the pleural dome into

two portions, a small medial and a large lateral, the former accommodating the accessory process, the latter the apex of the highest lung lobe.

The accessory process received a bronchus from the main epiarterial division; the vein from it passed in a curved manner over the upper and anterior border of the hilum to reach the upper main pulmonary vein.

A likely explanation of the causation of this anomaly is obtained by studying sections of embryos varying between 5 and 20 mm. lengths. Figs. 3 and 4, which are photographs from the well-known model of Piper's embryo (6·8 mm.), show most of the points with which we are concerned.

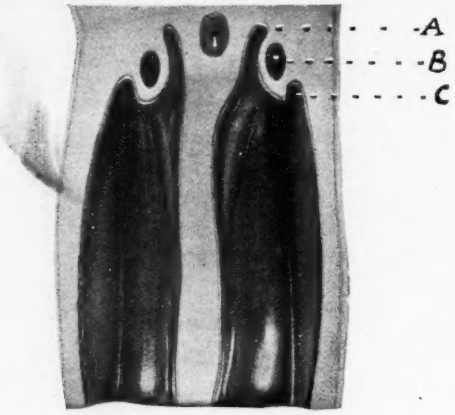

FIG. 3.—Posterior half of coronal section (model of Piper's embryo).

A, medial pleural apex; B, vena card. post.; C, lateral pleural apex.

In fig. 3 the elevation on the posterior body wall produced by the vena cardinalis posterior is seen to arch forward at its upper end, so that the vein is here carrying with it a fold of the primitive pleural membrane. This fold divides the apex of the pleuro-cœlomic cavity into medial and lateral segments, of which the medial is the higher and the more pronounced.

Fig. 4 shows the relationship of the lung bud to this fold: the lung, growing laterally, passes close to its lower border.

At a later stage the lung, expanding on the lateral aspect of the fold, will grow upwards into the lateral pleural apex. With the downward descent of the thoracic organs, the medial apex is pulled downwards, and so disappears; the vena azygos thus comes to occupy its normal relationship to the mediastinum and pleura.

But if before the medial pleural apex has quite disappeared a down-

ward pull on the fold should cause it to impinge, at the point where its curvature is greatest, posteriorly, against the lung bud so as to separate a process of pulmonary tissue, this process, so formed, would, as it grows and expands, push the medial pleural apex upwards again and prevent its disappearance.

Bluntschli and Fischer suggest that delayed transference (owing to late formation of some of its tributaries) of the vena subclavia from the vena cardinalis posterior to the vena cardinalis anterior may result in an outward pull of the fold at a later period than usual, and this, in conjunction

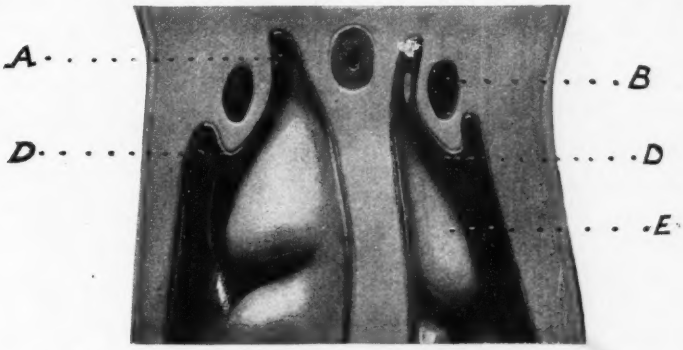

FIG. 4.—Anterior half of coronal section (model of Piper's embryo).

A, medial pleural apex; B, vena card. post.; D, fold containing vena card. post.; E, lung bud.

with the downward pull of the general thoracic contents, makes it more likely to produce a cleft in the lung substance.

The condition is a survival of a constant embryonic arrangement, and it is remarkable that the factors which occasionally cause its appearance do not more frequently give rise to its production.

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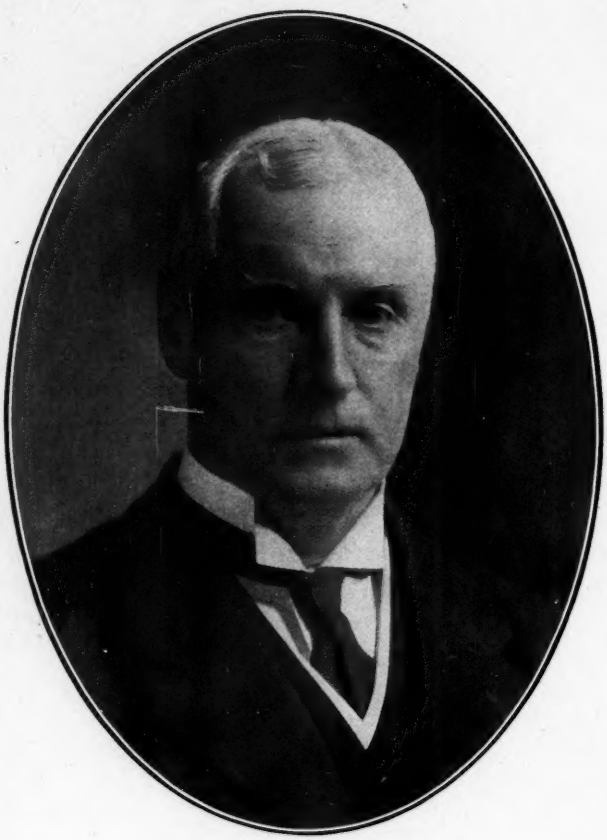

CHARLES BARRETT LOCKWOOD.

In Memoriam.

CHARLES BARRETT LOCKWOOD,

Born Sept. 23, 1856, *died Nov.* 8, 1914.

THE announcement of the death of Mr Lockwood has been to all those Anatomists who have been associated with him a cause of unfeigned sorrow. He had been so closely connected with the Anatomical Society from its earliest days, that his removal from our ranks leaves a blank which cannot be filled. In a sense, he was the founder of the Society, for, although for some years before its institution Sir G. Humphry had contemplated the formation of an Association of British Anatomists, it did not take definite shape until Mr Lockwood was associated with him in its organisation. The scheme was discussed during several week-end visits to Cambridge, and, when we three had arrived at a definite plan for the Society, Mr Lockwood willingly undertook the arduous task of enlisting the interests of the teachers of Anatomy in the London schools. As a result of his labours, the first preliminary meeting took place early in 1887 in Mr Lockwood's house, and the first public meeting was held at St Bartholomew's on May 6, 1887, with Humphry as President and Lockwood as Secretary.

In its early days it owed much of its vitality to his unremitting and judicious labours, both in his official and private capacity. His sound common-sense, logical mind, and untiring energy were important factors, contributing more than anything else to its development and growth, and it was as an acknowledgment of this obligation that in 1902 he was unanimously chosen as President.

The papers which he communicated to the Society were many and valuable, especially those on "The Development and Transition of

the Testis" (vol. xxi. 6, 35, and xxii. 38, 461, 505), "The Muscles, Ligaments, and Fasciæ of the Orbit" (xx. 1), and on "The Development of the Great Omentum and Transverse Mesocolon." Besides these, he also contributed shorter memoirs on "An Abnormality of the Fissure of Rolando" (xxiii. 16), on "A Right Aortic Arch" (xxiv. 4), on "Interruption of the Small Intestine" (xxiv. 13), on "Fossa around the Cæcum" (xxvi. 130), on "Adrenal Structures in the Inguinal Canal" (xxxiv. 79), and on "The Lymphatics of the Vermiform Appendix" (xxiv. 9).

Although of late his growing absorption in the elucidation of practical points in operative surgery took his attention away from Anatomy, yet he attended the meetings as regularly as his many professional engagements permitted, and his zeal in promoting its interests did not flag. All those who were associated with him in its work felt for him a very genuine and high esteem as an acute observer, a logical thinker, who combined an earnest interest in the morphological side of Anatomy with a clear conception of the bearings of the science on its practical application to surgery. It was the irony of fate that he who had done so much to elucidate the clinical history of septicæmia, especially in connexion with abdominal operations, should have died of this disease as a result of a slight puncture in operating for appendicitis.

His loss to anatomical science is very great, for in these days of specialisation the number of investigators in Anatomy who are at the same time practical surgeons is rapidly diminishing, and the divorce is a distinct disadvantage as regards the educational value of Anatomy to the medical student.

We owe to the kind courtesy of the Editor of the *Lancet* the excellent portrait of Mr Lockwood on p. 240.

A. M.